Exploring the geographical heterogeneity in production efficiency and metatechnology ratio of farms producing apple

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Abstract

The factors that cause ineffective use of the resources allocated to apple production and the regional distribution of these factors are among the research questions still waiting to be answered. In order to reduce this information gap, in this study, the efficiency of apple farms was measured and compared at the regional level by considering Isparta, Karaman, and Niğde provinces that constitute 45.8% of the total apple production in Turkey. Data acquired by interviewing from 175 farms selected with the stratified random sampling method constituted the primary material of study. The stochastic metafrontier approach was used for comparing interregional efficiency. Stochastic metafrontier results revealed that the metatechnology ratio was 79.7% in Isparta province, 75.9% in Karaman province, and 48.7% in Niğde province. According to metatechnology ratio results, the production frontier of apple farms in Isparta province is closer to metafrontier than the provinces of Karaman and Niğde. Giving importance to producer training, scientific studies, extension, and infrastructure studies will increase farms' efficiency. Besides, researcher-extension workers-farmers relations should be kept mutually strong.

Keywords: Apple. Stochastic metafrontier. Metatecnology ratio

1. Introductıon

Agriculture, which plays a vital role in economic development in underdeveloped countries, contributes significantly to economic well-being in developed and developing countries. In many developing countries, agricultural development is significant to ensure the food security of communities. Agriculture is a much more critical sector, especially in countries with low per capita income.

According to TURKSTAT (2020) data, Turkey's agricultural sector covered approximately 6.42% of the Gross Domestic Product and 18.15% of the total employment in 2019. In Turkey, to make the agricultural sector's growth indicators, which a growth trend permanent, efforts to develop sustainable policies continue. Increasing productivity and ensuring efficiency are among the most important goals of these policies.

After the 1960s, the demand for food increased with the population growth globally. These developments highlighted the needed to develop agricultural policies. As a result, the increase in the use of the qualified workforce, fertilizer, machinery, and breeding material has been applied and increased the sector's productivity (Bozdemir, 2017).

Fresh fruits and vegetables are one of the food sectors that are continually in demand and on the agenda with productivity problems. Although there were fluctuations in their production over the years, approximately 2.01 billion tons of fresh fruit and vegetables were produced globally in 2019. This production consisted of 56.13% of vegetables, 43.87% of fruits (FAO, 2020). Turkey is located in an important place because of the ecological advantages and covers approximately 2.42's% of the world's fresh fruit and vegetable production.

In Turkey, pomiculture is an important sub-sector in terms of being directly related to people's nutrition, being the subject of export and import, and providing raw materials to the sector that derives its raw material from fruit growing (Esengün, 1993). It was produced about 20 million tons of fruit in Turkey in 2019. Pome fruits constituted 21.5% of the fruits produced. With 3.6 million tons, apple was the second most-produced fruit species after grape (FAO, 2020).

Although apple cultivation is done intensively in certain regions in Turkey, it can be cultivated in almost every region. As in many agricultural production branches, the transition rate to modern agriculture is slow in apple growing. Especially as a result of the policies and programs (such as certified sapling usage support, agricultural insurance support, supporting rural development investments) and extension activities developed in recent years, the establishment of modern orchards with clonal rootstocks has gained speed. This change is essential for apple cultivation. Apple appeals to the taste and income level of the majority of people. Therefore, apple has a wide range of trade. Although Turkey is one of the world's largest producer of apples, the country is not in the desired position in foreign trade and productivity.

Agricultural productivity, growth, and resource use are considered the essential elements of sustainable production and profitability. Achieving productivity and sustainability in agriculture will be possible by using production inputs effectively. In Turkey, as well as developed countries, there is excessive use of inputs to increase production. This situation has a negative impact on the destruction of natural resources and the environment. The effective use of resources can reduce these negative impacts (Gündüz et al., 2011).

Efficient use of scarce resources is essential for those who use resources and for all economies. As a result of that, it is very important to determine which enterprises that achieve similar outputs using similar inputs are efficient. It is also necessary to determine why some enterprises are inefficient and lay out what they should do to be sustainable. For this purpose, parametric stochastic frontier analysis (hereafter SFA) and nonparametric data envelopment analysis (hereafter DEA) have been commonly used performance measurement methods. Nevertheless, SFA and DEA determine a production frontier and evaluate all enterprises according to this production frontier.

Faced with different production opportunities, enterprises choose from different sets of feasible input-output combinations. These combinations, which can be different for each region, are called technology sets. For example, characteristics such as the type and size of the machinery, the quality of the workforce, economic infrastructure (such as the number of airports, access to the market), resource endowments (such as soil quality, climate, energy resources), and the physical, social and economic environment in which production takes place may be different. Such differences have separated the production frontier and led to studies that determine different enterprises' activities (O'Donnell et al., 2008).

It is common and simple to estimate a production frontier using enterprise data and measure its relative performance within the group. However, there is generally a great interest in measuring the performance of enterprises among groups. Unfortunately, such comparisons significant only in the limiting specific case where the frontiers are the same. As a general rule, efficiency levels measured for different frontiers cannot be compared with each other (O’Donnell et al., 2008). In this way, it is possible to compare enterprises with different production frontiers by using the metafrontier function.

Many studies were carried out to determine the efficiency of farms in Turkey. In addition, DEA and SFA methods were used in most of these studies. The number of efficiency analysis using the metafrontier function has been quite limited. In this study, the apple farms' efficiency in Turkey for the first time has been determined by taking into account the climate and soil characteristics.

Apple is commercially produced Isparta, Karaman, Niğde, Antalya, Denizli, Konya, and Kayseri provinces, in Turkey. Isparta, Karaman, and Niğde constituted 45.8% of the total apple production in 2019 and were the most apple-producing provinces. When evaluated in terms of production value and modern cultivation techniques, Isparta, Karaman, and Niğde provinces are the center of Turkey's apple production. In these provinces, intensive inputs are used at every phase of apple production. Thus Isparta, Karaman, and Niğde provinces have been selected as the research area.

This study aimed to determine and compare the efficiency of apple farms at the regional level. It is thought that this study will contribute to the literature and be a guide for future studies.

2. Literature Review

Many studies on the efficient use of scarce resources, which are essential for all countries' economies, have been carried out. SFA and DEA methods were used as performance measurement methods in most of these studies. However, few efficiency studies were using the metafrontier function. Including two in Turkey, four studies have been found on the efficiency of apple farms.

In the first of these studies, Gül (2005) measured the efficiency using DEA, the data from 60 apple farms in the Antalya province during the 2001 production period. Analysis results revealed that 14 farms under constant return to scale assumption and 30 farms under variable return to scale assumption were thoroughly efficient. In the study, apple farms' technical efficiency was estimated to 69% and 92% under constant and variable return to scale assumptions.

In the second study, Gül (2006) carried out a similar study in Isparta, Karaman, and Niğde provinces. DEA was used in the study in which the technical efficiency of apple farms was determined. Data were collected from 129 apple producers in the 2001 production season through questionnaires. Analysis results revealed that 19 farms under constant return to scale assumption and 66 farms under variable return to scale assumption were thoroughly efficient. In the study, apple farms' technical efficiency was estimated to 60% and 90% under constant and variable return to scale assumptions.

In the third study, Murtaza and Thapa (2017) determined the efficiency of small-scale apple farms in Pakistan. According to the data obtained from 181 apple producers, the farms were divided into three groups as lower-small (less than 11 acres), medium-small (11-21 acres), and upper-small (over 21 acres). The technical efficiency of farms, according to DEA results, varied between 21% and 100%. In data evaluated according to farm size, technical efficiency was found 71.5% in lower-small farms, 78.5% in medium-small farms, and 80.6% in upper-small farms. In other words, as the farmland increased, the efficiency rate increased.

In the fourth study on apple farms in the Korça region of Albania, Osmani and Kambo (2019) evaluated the data obtained from 150 apple producers using the SFA method. According to the Cobb-Douglass production function, the farms were at minimum 0.74, maximum 0.95, average 0.88 efficiencies, while according to the Translog production function, these values were found 0.73, 0.97, and 0.90, respectively. Access to advisory services, average apple plot size, and the number of apple plots positively affected efficiency, while education and modern orchards were negatively affected.

As farms operating in different regions or using different technologies face different input-output combination opportunities, their efficiency is likely to vary. Therefore, not considering the technological differences between regions leads to a wrong estimation of efficiency and misinterpretation. From this point of view, Hayami and Ruttan (1971) developed a metafrontier approach that considered the metatechnology ratio (hereafter MTR) and compared different groups' technical efficiency. Later, Battese and Rao (2002) introduced the stochastic frontier approach in predicting different groups' efficiency in the metafrontier approach. Battese et al. (2004) and O'Donnell et al.(2008) changed this approach by introducing a mixed two-step procedure. The first step is based on technical efficiency prediction, while the second step is based on linear programming for metafrontier prediction.

In recent years, there has been an increase in the number of studies comparing different regions and different characteristics (such as variety, size) in which the metafrontier approach is used. O'Donnell et al. (2008) estimated the efficiency and the technological gap with 5-year data from 97 countries to explain the metafrontier approach.

Kabir and Kahn (2010) predicted the efficiency of small-scale biogas plants in five different regions in Bangladesh with a data envelopment metafrontier approach. The results showed regional differences in regional technical efficiency, metafrontier technical efficiency, and technological gap.

Villano et al. (2010), with the stochastic metafrontier (hereafter SMF) approach, discussed pistachio production efficiency in the Kerman province of Iran based on pistachio varieties (Kalleh-ghuchi, Fandoghi, and Akbari). They estimated that there were differences in the efficiency among farms growing different varieties and reported that this technological gap resulted from inputs.

Onumah et al. (2013) determined the technological gap and technical efficiency of the organic and conventional cocoa-producing farms in Ghana using the SMF approach. In the study, data of 390 farms, 200 of which were organic producers, were used. According to the results, the mean metafrontier technical efficiency of organic farms was estimated to be 59%, and that of conventional farms was estimated to be 71%.

Henningsen et al. (2015) determined the efficiency of farms growing sunflower in Tanzania according to their contracted production status. A survey was carried out with a total of 396 sunflower farms, including 201 contracted producers. It was reported that the MTR of contracted producing farms was high.

Mensah and Brümmer (2016) evaluated Ghana's mango production efficiency with the SMF approach for three different regions. In the study, the rate of technological gap ranged from 48% to 79%.

Owusu and Bravo-Ureta (2020) investigated the effect of planting time on-farm efficiency in groundnut cultivation. The authors reported that the metafrontier technical efficiency calculated with the SMF approach was 83% in early planting and 54% in late planting.

There was no study in Turkey and the world in the literature review that determined apple farms' efficiency using the metafrontier approach.

3. Material and Method

3.1. Conceptual framework

This study creates three different frontiers in order to compare the apple production level to the maximum potential yield, characterized by the metafrontier approach for Isparta, Karaman, and Niğde provinces. However, it is unlikely to compare farms in regions with different production frontiers in terms of efficiency. In other words, we cannot say that a farm operating in one region is more efficient than a farm operating in another region. However, the metafrontier approach shown in Figure 1 allows the comparison of farms with different production frontiers.

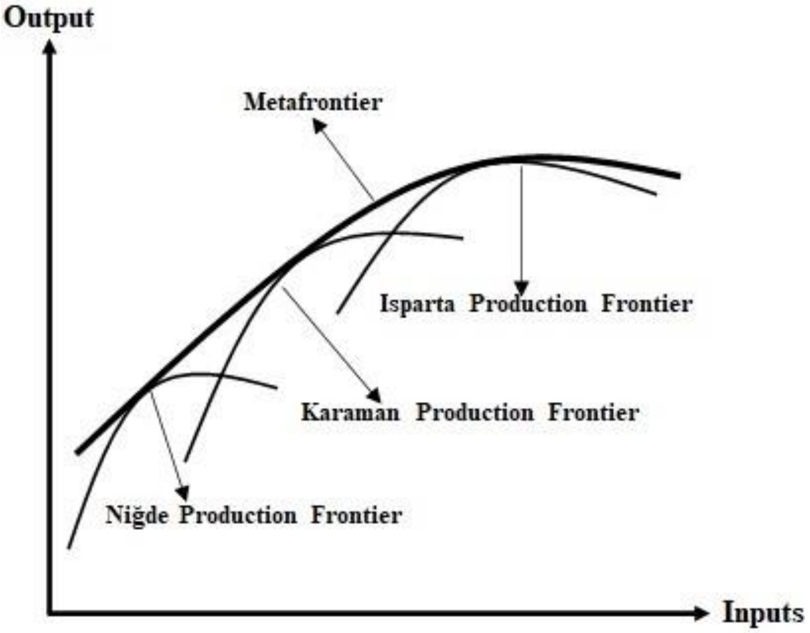


Figure 1: Metafrontier function model (Adapted O'Donnell et al., 2008)

3.2. Theoretical framework for the study and model specification

SFA estimates the production frontier by using econometric techniques. When considering different regions in apple cultivation, a stochastic approach is stated as follows:

$$y_{it} = f(x_{1it}, x_{2it}, \ldots, x_{Nit}; \beta^k) e^{V_{it}^k - U_{it}^k} = e^{x_{it}'\beta^k + V_{it}^k - U_{it}^k}$$
(1)

Where the variable Y is the production of farm ith in the region kth; x represents an input vector for region kth as used by ith farm; β is a parameter vector for input factors in the frontier model for the kth region (k=1,2,...,K); V_{it}^k is the symmetric random term assumed to be independently distributed and identical to zero mean and constant variance. u_{it}^k is a non-negative independent random variable that reflects the technical inefficiency by using specific characteristics that belong to the ith farm. Battese and Coelli (1995) explained the changes in u_{it}^k, which express technical inefficiency, with the following model:

$$u_i = z_i \delta \quad (2)$$

In the above equation (2), $\boldsymbol{z}_i$ represents certain characteristics (such as age, education level) that affect technical efficiency, and δ represents parameters. With the SFA approach, a farm's efficiency is determined by proportioning the observed output to the expected output in equation 1 (Coelli et al., 2005). From this point of view, technical efficiency can be formulated as follows:

$$TE = \frac{e^{x_i\beta+v_i-u_i}}{e^{x_i\beta+v_i}} = e^{-u_i} \quad (3)$$

u_i=0 means the farm is fully efficient. Using the equation numbered 3 above, a separate production frontier was determined for Isparta, Karaman, and Niğde provinces (k=1,2,3). Depending on the production frontier determined, it is necessary to test whether the apple farm in each province uses the same technology. The likelihood (LR) formula given below was used for this.

$$\boldsymbol{LR(\lambda) = -2\,\{\ln[L(H_0)] - \ln[L(H_1)]\}} \quad (4)$$

In equation (4), $\boldsymbol{L(H_0)}$ represents the log-likelihood ratio of the stochastic frontier function for pooled data, where the total of farms in Isparta, Karaman, and Niğde provinces are evaluated, while $\boldsymbol{L(H_1)}$ represents the sum of the log-likelihood ratios of individual provinces. The calculated $\boldsymbol{LR(\lambda)}$ value indicates that it will be appropriate to use metafrontier if rejecting the null hypothesis assuming the provinces' stochastic frontier model is the same (Battese et al., 2004).

Stating that the metafrontier function's deterministic estimation would give more reliable results, O'Donnell et al. (2008) defined a deterministic metafrontier production function as follows.

$$\boldsymbol{y^*_{it} = f(x_{1it}, x_{2it}, \ldots\ldots, x_{Nit}\,; \beta)\mathrm{e}^{x'_{it}\beta}} \quad (5)$$

In equation (5), y denotes the metafrontier output, β denotes a vector of metafrontier parameters satisfying the constraints.

$$\mathbf{x}'_{it}\boldsymbol{\beta} \geq \mathbf{x}'_{it}\boldsymbol{\beta}^{k} \qquad \text{for all } k = 1, 2, \ldots, K \quad (6)$$

The restrictions given in equation (6) imply that the metafrontier function cannot fall below any group frontiers and is supported by only one data generation process. Battese et al. (2004) reported that obtaining better results by solving the optimization problem considers the minimization of the sum of absolute deviations of the distance between the k^{th} group frontier and metafrontier. In this study, the function that considers the minimization of the sum of the absolute deviations is used in the metafrontier estimation. This function is given below.

$$\min_{\beta} \sum_{i=1}^{L} \sum_{t=1}^{T} [\ln f(x_{1it}, x_{2it}, \ldots, x_{Nit}; \beta) - \ln f(x_{1it}, x_{2it}, \ldots, x_{Nit}; \hat{\beta}^k)]$$

$$\text{s.t.} \quad \ln f(x_{1it}, x_{2it}, \ldots, x_{Nit}; \beta) \geq \ln f(x_{1it}, x_{2it}, \ldots, x_{Nit}; \hat{\beta}^k$$

for all *i* and *t*; (7)

Where $\hat{\beta}^k$ is the estimated coefficient vector of the k group associated with the stochastic frontier. As in the study of O'Donnell et al. (2008), the parameters in this study were assumed as log-linear. In this case, linear programming turns into the following form:

$$\min_{\beta} \bar{\mathbf{x}}' \beta$$

$$s.t. \quad \mathbf{x}'_{it} \beta \geq \mathbf{x}'_{it} \hat{\beta}^k \qquad \text{for all } i \text{ and } t, \tag{8}$$

Where $\bar{\mathbf{x}}$ is the arithmetic mean of the x_{it} vectors over all farms in all periods. The 3000 iterative bootstrapping methods were used to estimate the standard errors of the Metafrontier production function parameters.

After solving the linear programming defined by equation (8), the MTR and technical efficiency concerning metafrontier can be obtained by the following formula by decomposing equation 1:

$$y_{it} = e^{-U_{it}^k} * \frac{e^{x'_{it}\beta^k}}{e^{x'_{it}\beta}} * e^{x'_{it}\beta + V_{it}^k} \tag{9}$$

According to the k^{th} group frontier, the first term on the right-hand is the i^{th} farm's technical efficiency defined in equation 3. The second term on the right-hand gives the MTR for i^{th} farm in group k^{th}. In this way, MTR is shown as follows:

$$\mathbf{MTR}_{it}^{k} = \frac{e^{x_{it}'\beta^{k}}}{e^{x_{it}'\beta}} \tag{10}$$

The MTR varies between 0 and 1. This ratio enables the efficiency of farms in a region to be compared according to metefrontier. MTR provides comparing the competitiveness of agricultural enterprises in different regions. As a result, the above equations express that the technical efficiency of the firm i^{th} regarding metafrontier is as follows:

$$\mathbf{TE}_{it} = \frac{y_{it}}{e^{x_{it}'\beta + V_{it}^{k}}} \tag{11}$$

In practical terms, it is possible to estimate the metafrontier technical efficiency using decomposition.

$$\widehat{\mathbf{TE}}_{it} = \widehat{\mathbf{TE}}_{it}^{k} * \mathbf{M\hat{T}O}_{it}^{k} \tag{12}$$

Where $\widehat{\mathbf{TE}}_{it}^{k}$ and $\mathbf{M\hat{T}O}_{it}^{k}$, are estimators.

The selection of the production function is significant as it can affect the efficiency results. Production functions such as Translog and Cobb-Douglas have been used in many studies (O'Donnell et al., 2008; Çobanoğlu, 2013; Gündüz et al., 2016; Oğuz and Canan, 2016; Hazneci and Ceyhan, 2017; Villano et al., 2019; Watto and Mugera, 2019; Issahaku and Abdulai, 2020). In this study, the Translog production function was used because the data fit better than the Cobb-Douglas production function. The compatibility of the translog production function was tested with the log-likelihood formula given below.

$$\boldsymbol{LR(\lambda) = -2\,\{\ln(LR_1) - \ln(LR_0)\}} \tag{13}$$

In equation (13), $\boldsymbol{L(R_1)}$ represents the log-likelihood ratio of the Cobb-Douglas stochastic frontier function, $\boldsymbol{L(R_0)}$ represents the log-likelihood ratio of the Translog stochastic frontier function. The calculated LR(λ) value indicates that it will be appropriate to use the Translog production function if rejecting the null hypothesis, assuming the Cobb-Douglas stochastic frontier function is compatible (Battese et al., 2004).

The SFA estimates obtained with the translog functional assumption are defined for the k region as follows:

$$\ln y_{it} = \beta_0^k + \sum_{j=1}^{5} \beta_j^k \ln x_{jit} + 0.5 \sum_{j=1}^{5} \sum_{m=1}^{5} \beta_{jm}^k (\ln x_{jit})(\ln x_{mit}) + V_{it}^k - U_{it}^k$$

(14)

Where $\ln x_{jit}$ is the logarithm of the inputs and $\ln y_{it}$ is the logarithm of the output. While the output variable was apple yield as kilograms per hectare ($y_{(yield)}$=kg ha^{-1}), the input variables were total apple land as a hectare ($x_{1(apple\ land)}$=ha), total machinery use calculated as horsepower ($x_{2(Machinery)}$=h ha^{-1}), total pesticide cost as Turkish Liras ($x_{3(Pesticide)}$=TL ha^{-1}), total labor use calculated as man-days labor unit ($x_{4(Labor)}$=h ha^{-1}), and used fertilizer, which was the amount of active nitrogen, phosphorus, and potassium ingredients ($x_{5(NPK)}$=kg ha^{-1}).

The inefficiency model used in the study is as follows:

$$\mu_i = \delta_0 + \sum_{m=1}^{7} \delta_m Z_{mi} \qquad (15)$$

Where Z_1 represents the age of farmer (year); Z_2 represents the education level of the farmer (year); Z_3 denotes non-farm income which is a dummy variable that has the value of one if it has non-farm income, zero if it does not; Z_4 represents the experience of the farmer (year); Z_5 denotes the farmers' debt which is a dummy variable that has the value of one if it has dept, zero if it does not; Z_6 denotes the case of having a soil analysis which is a dummy variable that has the value of one if farmers have a soil analysis, zero if they do not; Z_7 represents the number of irrigation.

SFA technical efficiency of apple farms was estimated using FRONTIER 4.1 software developed by Coelli (1996). JMP software was used for the Bootstrap method. To obtain metafrontier parameters was used SHAZAM 11.1 econometric software, whose codes were given in Appendix.

3.3. Study area and sampling procedure

Isparta, Karaman, and Niğde provinces were selected as the research area (Figure 2). Eğirdir, Gelendost, and Senirkent districts in Isparta province; Central district in Karaman province, Merkez, Bor, and Çamardı districts in Niğde province were selected by purposive sampling method. As the coefficient of variation was higher than 75%, the Neyman Method, one of the stratified random sampling methods, was used in determining the number of apple farms to be questionnaires. The number of apple farms to be questionnaire was calculated with the following equation (Yamane, 2001).

$$n = \frac{(\sum N_h S_h)^2}{N^2 D^2 + \sum N_h S_h^2} \quad (16)$$

In Equation (16), n: sample size, N: total number of apple farms, N_h: number of apple farms in the h^{th} group, S_h: standard deviation of the h^{th} group, and D is the margin of error that is allowed the mean deviation. The margin of error that is allowed for the mean deviation is found with the equation D=d/z. In this equation, d is the allowable margin of error and z is the table value in the determined confidence level.

The number of sample apple farms was calculated as 175 with a 5% margin of error (the level of precision) and a 90% confidence level (z=1.65) using the sampling method. The distribution of the 175 farms by provinces was as follows: 80 in Isparta province, 43 in Niğde province, and 52 in Karaman province. Data referred to the 2017-2018 production season.

Figure 2: Research area

4. Results and Discussion

Descriptive statistics for the parameters used in obtaining efficiency scores of the provinces were given in Table 1. The average age, according to the average of farms, was 52.44 years. While the Karaman province producers had the highest age group with an average age of 54.85, Isparta province had the lowest age group with 49.94. Apple producers in Niğde province were on average 54.16 years old. Although the experience in apple cultivation of the provinces was close to each other, Niğde province producers stood out as the most experienced province with 27.40 years. The education level of the farmers was very close to each other in all three provinces. When evaluated overall, it was determined that the producers had an average of 24.46 years of experience and had 7.92 years of education. The results showed that 59% of the farmers were non-debted, and 38% of them analyzed the soil. Farmers in Isparta, Karaman, and Niğde produced on average 56240 kg/ha, 41240 kg/ha, and 16133 kg/ha of apples, respectively. Overall, farmers allocated an average of 3.54 hectares of land, 106 hours of machinery, 7804 Turkish Liras (hereafter TL) of pesticide cost, 898 hours of labor, and 317 kg of fertilizer to produce apples.

Table 1: Descriptive statistics of the variables used in the efficiency models*

	Isparta	Karaman	Niğde	Pooled
Economic variables				
Yield (kg ha^{-1})	56240.39 (16262.43)	41240.45 (11417.83)	16133.72 (4724.67)	41928.48 (20552.86)
Apple land (ha farm^{-1})	2.93 (3.14)	4.39 (3.98)	3.67 (4.29)	3.54 (3.74)
Machinery (h ha^{-1})	124.10 (56.80)	86.95 (38.94)	94.91 (74.19)	105.89 (59.39)
Pesticide (TL ha^{-1})	9640.45 (3408.53)	6686.33 (2573.95)	5739.87 (3816.32)	7804.23 (3702.58)
Labor (h ha^{-1})	1001.31 (344.31)	895.92 (268.83)	709.98 (473.53)	898.41 (377.86)
NPK (kg ha^{-1})	342.97 (130.41)	289.06 (155.67)	303.42 (511.67)	317.23 (280.37)
Farmer and farm characteristics				
Age (year)	49.94 (11.02)	54.85 (9.69)	54.16 (11.61)	52.43 (10.98)
Education (year)	8.10 (2.89)	8.13 (3.33)	7.33 (3.40)	7.92 (3.15)
Non-farm income (Dummy 1:yes)	0.41 (0.50)	0.40 (0.50)	0.72 (0.45)	0.49 (0.50)
Experience (year)	24.61 (9.29)	21.81 (7.24)	27.40 (12.94)	24.46 (9.96)
Farmers' debt (Dummy 1:yes)	0.56 (0.50)	0.48 (0.50)	0.77 (0.43)	0.59 (0.49)
Have a soil analysis (Dummy 1:yes)	0.21 (0.41)	0.62 (0.49)	0.42 (0.50)	0.38 (0.49)
Number of irrigation	28.01 (16.01)	19.13 (9.97)	13.81 (12.33)	21.89 (14.76)

*Data in the parentheses showed standard deviations.

Provincial-level and pooled model efficiency scores were calculated using the variables were given in Table 1. The various hypotheses were tested to determine the model's fitness and accuracy for each province and the pooled model. Test findings of the hypotheses were presented in Table 2. In the first stage, the null hypothesis that the Cobb-Douglas production function was the best model was tested with the likelihood ratio test (LR) based on provinces and pooled model. The null hypothesis assuming that the Cobb-Douglas production function was the best was rejected. Therefore, the translog production function was determined as the best-fitted model. Secondly, all of the hypotheses that test the presence of inefficiency were rejected based on provinces and pooled model. In the third hypothesis, the hypothesis that the efficiency was not stochastic was rejected for all models, and it was determined that the stochastic frontier function was the most fitted model. Finally, the null hypothesis that the regional production frontier of apple farms in Isparta, Karaman, and Niğde provinces was similar and that the data at the provincial level were obtained from one production frontier under similar conditions were rejected. The results showed that require the calculation of metafrontier technical efficiency and comparisons should be made by metafrontier technical efficiency.

Table 2: Hypotheses tests

Null Hypothesis	LR Statistics (λ)	Critical Value (0.05)*	Decision
1. $H_0:\beta_{ij}=0$			
Isparta	130.416	24.384	H_0 Rejected
Karaman	112.358	24.384	H_0 Rejected
Niğde	64.129	24.384	H_0 Rejected
Pooled	101.536	24.384	H_0 Rejected
2. $H_0:\gamma=\delta_1=\delta_2=\delta_3=\delta_4=\delta_5=\delta_6=\delta_7=0$			
Isparta	60.900	16.274	H_0 Rejected
Karaman	56.986	16.274	H_0 Rejected
Niğde	31.053	16.274	H_0 Rejected
Pooled	-42.725	16.274	H_0 Rejected
3. $H_0:\gamma=0$			
Isparta	16.336	2.706	H_0 Rejected
Karaman	10.941	2.706	H_0 Rejected
Niğde	6.671	2.706	H_0 Rejected
Pooled	-67.420	2.706	H_0 Rejected
4. $H_0:f_{Isparta}(X;\beta_{Isparta}) = f_{Karaman}(X;\beta_{Karaman}) = f_{Niğde}(X;\beta_{Niğde})$			
Pooled	383.327	30.814	H_0 Rejected

*Critical values were taken from Kodde and Palm (1986).

Statistical results of stochastic production frontier and metafrontier were presented in Table 3. It was assumed that the variables found to be statistically significant affect the output. However, it should not be forgotten that the law of diminishing returns in agriculture is valid, and it should be known and taken into consideration that the yield cannot be increased continuously by increasing the inputs.

The rate of returns to scale was also determined in the study. If the calculated coefficient is greater than 1, it means an increasing returns to the scale; if it is equal to 1, it means constant returns to the scale, and if it is less than 1, it means a decreasing returns to the scale. The results showed increasing returns to scale in Karaman and Niğde provinces, decreasing returns to scale in Isparta province and pooled model (Table 3).

The fact that the gamma values were very close to 1 and statistically significant indicates that the farms were not managed effectively, and the production factors were not used effectively. In other words, it can be said that the inefficiencies were due to the farms or farmer characteristics.

The analysis results laid out that the variables' statistical significance added to the model changed based on provinces and pooled model. In Isparta province, machinery, pesticide cost, labor, and NPK were statistically significant. Whereas machinery, pesticide cost, and labor positively have affected efficiency, NPK has affected negatively. Increasing the amount of machinery, pesticide cost, and labor used by 1% increases efficiency by 0.96%, 2.86%, and 6.14%, respectively. On the other hand, a 1% increase in the amount of NPK causes a 3.98% decrease in efficiency. Considering that the cost of pesticides is directly proportional to the number of applied pesticides, it can be said that the excess pesticide application has a positive effect on efficiency. However, based on this result, pesticides should not be unconsciously applied to increase yield; human and environmental health should be considered.

In Karaman province, apple land, pesticide cost, and labor were found to be statistically significant. While apple land and labor have affected the efficiency positively, the pesticide cost has affected negatively. Increasing the apple land and labor used by 1% increases efficiency by 2.80% and 4.12%, respectively. On the other hand, a 1% increase in the pesticide cost causes a 2.49% decrease in efficiency. Unlike Isparta, the increase in the pesticide cost in Karaman province has affected the efficiency negatively. It is thought that the reason for this is that the apple producers in Isparta were more experienced than other provinces and that the pesticide application on time. Moreover, such as the quality of the pesticide used, applied time, the weather when the pesticide is applied, many factors affect the applied pesticide success.

Niğde province results showed fewer variables were found to be statistically significant compared to the other two provinces. While apple land has affected the efficiency positively, the labor has affected negatively. Increasing the labor used by 1% increases efficiency by 2%, increasing the apple land causes a 2.62% decrease in efficiency. According to pooled model, the labor and NPK have affected the efficiency positively, the machinery has affected negatively. Increasing the labor and NPK by 1% increases efficiency by 1.32% and 1.27%, respectively, although a 1% increase in the machinery causes a 2.49% decrease in efficiency.

As in the studies of Gündüz et al. (2011), Özden and Öncü (2016), Abdulai et al. (2018), Osmani and Kambo (2019), in this study as well, the farmland variable was found to had a positive effect on efficiency for Isparta and Karaman provinces. While the machinery variable had a negative effect on productivity for Karaman province, it had a positive effect for Isparta and Niğde provinces. Kaçıra (2007), in maize production, Parlakay, and Alemdar (2011), in peanut production, predicted that the use of machinery had a positive effect on efficiency. Parlakay and Alemdar (2011) found that a 1% increase in machinery increased the efficiency by 0.09%, and Osmani and Kambo (2019) increased by 0.17%.

The pesticide cost variable had a positive effect on efficiency in Isparta and Niğde provinces and negatively in Karaman. Parlakay and Alemdar (2011) and Osmani and Kambo (2019) estimated that applying pesticides affected efficiency positively. A 1% increase in labor increases the efficiency by 6.14% in Isparta, 4.12% in Karaman, and 2.01% in Niğde. Guesmi et al. (2012), Hasnain et al. (2015), and Abdallah and Abdul-Rahman (2019) estimated a 1% increase in labor, a 0.08%, 0.002%, and 0.17% increase in efficiency, respectively. The NPK variable negatively has affected efficiency in Isparta. Although it was not statistically significant, it positively affected the provinces of Karaman and Niğde. It is thought that this difference between provinces is due to more conscious fertilization result from having the higher rate of soil analysis in Karaman and Niğde provinces. Abdulai et al. (2018) and Osmani and Kambo (2019) showed that fertilizer had a positive effect on efficiency; however, Akamin et al. (2017) reported that it adversely affected efficiency.

Table 3: Parameter estimates of the stochastic frontier and metafrontier models

Variable	Isparta		Karaman		Niğde		Pooled		Metafrontier	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Constant (β_0)	11.387***	0.993	2.392**	1.163	5.464***	0,966	2.797***	3.953	-0.6300	13.039
LnAppleLand (β_1)	0.260	0.390	2.803***	0.392	-2.621***	0,525	-0.031	-0.051	1.0778	0.539
LnMachinery (β_2)	0.956*	0.543	-0.335	0.854	0.972	0,879	-1.312**	-2.164	-0.5179	1.543
LnPesticide (β_3)	2.861***	0.569	-2.492***	0.401	0.563	0,519	0.313	0.492	0.6951	1.941
LnLabor (β_4)	6.136***	0.879	4.121***	0.705	2.006***	0,509	1.323**	2.430	1.4459**	2.878
LnNPK (β_5)	-3.984***	1.272	0.0009	0.699	0.204	0,442	1.271*	1.892	0.9639*	1.994
½ $LnAppleLand^2$ (β_{11})	0.070***	0.021	-0.094	0.075	0.981***	0,252	0.038	0.680	0.0294***	0.014
LnAppleLand*LnMachinery (β_{12})	0.150***	0.027	-0.141*	0.074	0.169**	0,076	0.155**	2.364	0.0542	0.034
LnAppleLand*LnPesticide (β_{13})	0.051	0.039	0.268***	0.048	0.246*	0,127	-0.034	-1.222	-0.2496	0.039
LnAppleLand*LnLabor (β_{14})	-0.274***	0.044	0.737***	0.068	-0.216*	0,113	-0.087	-1.323	-0.0228	0.061
LnAppleLand*LnNPK (β_{15})	0.021	0.046	-0.213***	0.063	-0.569**	0,156	0.049	1.114	0.1070*	0.050

½ $LnMachinery^2$ (β_{22})	-0.165***	0.064	0.148	0.139	-0.007	0,214	-0.553***	-2.994	-0.5151	0.154
LnMachinery*LnPesticide (β_{23})	-0.279***	0.092	-0.652***	0.133	0.153*	0,089	0.182***	2.883	0.0429	0.142
LnMachinery*LnLabor (β_{24})	0.101	0.103	1.056***	0.173	-0.331**	0,118	-0.072	-0.739	0.1698***	0.210
LnMachinery*LnNPK (β_{25})	0.112	0.121	0.036	0.087	-0.388**	0,091	0.377***	3.392	0.1849	0.154
½ $LnPesticide^2$ (β_{33})	0.448***	0.140	-0.309***	0.079	-0.304**	0,154	0.170	1.167	0.3023	0.215
LnPesticide*LnLabor (β_{34})	-0.767***	0.067	0.529***	0.072	0.113	0,090	-0.300***	-5.641	-0.2411	0.224
LnPesticide*LnNPK (β_{35})	-0.418***	0.104	0.790***	0.091	-0.074	0,075	-0.044	-0.523	-0.1735	0.171
½ $LnLabor^2$ (β_{44})	-0.287	0.188	-1.220***	0.171	-0.530**	0,180	0.326***	3.005	-0.1405*	0.467
LnLabor*LnNPK (β_{45})	0.327**	0.144	-0.487***	0.052	0.168	0,105	-0.045	-0.537	0.1520	0.241
½ $LnNPK^2$ (β_{55})	1.442***	0.216	-0.655***	0.124	0.738***	0,177	-0.509***	-5.281	-0.3452	0.254
Returns to scale ($=\sum_{i=1}^{k}\beta_i$)	0.578		10.922		1.929		0.637			
Sigma-square (σ^2)	0.042***	0.012	0.039***	0.013	0.023**	0,012	0.360***	0.043		
Gamma (ɣ)	0.999***	0.00052	0.999***	0.000008	0.970***	0,0797	0.999***	0.00543		
Log-likelihood (Log L)	60.900		56.986		31.053		-42.725			
Likelihood ratio (LR) test	116.376		99.924		26.833		87.750			

*Denotes significance at 10%, **Denotes significance at 5%, ***Denotes significance at 1%.

Parameter estimates of the factors affecting the inefficiency of the farms were given in Table 4. As shown in Table 4, the age of the farmhead positively affected the farmer performance in Isparta and negatively in the provinces of Karaman, Niğde, and pooled model. While the age variable was not statistically significant for Karaman province and pooled model, it was significant for Isparta and Niğde provinces. In the study was carried out with kiwi producers, it was determined that the farmers' age with efficient farms was higher than the inefficient ones, so the age variable had a positive effect on the farms' efficiency (Canan et al., 2018). Gündüz et al. (2016) reported that the farmer's age negatively affected efficiency in tomato-producing farms, as in the provinces of Karaman and Niğde in this study. Osmani and Kambo (2019) also found that the age variable negatively affected technical efficiency.

The education variable has affected the technical efficiency positively in Isparta, Karaman provinces, and negatively in Niğde province. The education variable was statistically significant in all three provinces and pooled model. Results showed that the higher the farmer's education level, the higher the farms' efficiency level. Similar results were obtained in many studies (Gündüz et al., 2016; Akamin et al., 2017; Hazneci and Ceyhan, 2017; Murtaza and Thapa, 2017; Osmani and Kambo, 2019).

The non-farm income variable of the farmer has affected the technical efficiency negatively in the pooled model. It is possible to refer to a similar situation in the province of Isparta. Isparta and pooled model were statistically significant. In other words, the fact that the farms have non-farm income has affected their efficiency negatively. It is thought that the efficiency was negatively affected as the farms with non-farm income do not perform the necessary actions in apple cultivation (such as apply pesticides, fertilization) on time due to time constraints.

The experience variable was statistically significant in Isparta, Karaman, and Niğde provinces, but not significant in the pool model. Whereas the efficiency decreased as the experience increased in the Isparta province, the efficiency increased as experience increased in the Karaman and Niğde provinces. It is estimated that this case is because apple production in Isparta was older than the provinces of Karaman and Niğde and that the apple producers in Isparta were a traditionalist. Gündüz et al. (2016) predicted that tomato farmers' experience increased technical efficiency; Canan et al. (2018) reported that efficient farms were more experienced in kiwi farms than inefficient farms. Murtaza and Thapa (2017) predicted that the experience increased the Katja and Red Delicious apple cultivars' technical efficiency in producing farms. Osmani and Kambo (2019) also emphasized that experience played a role in increasing technical efficiency in apple farms.

The farmers' debt variable was not statistically significant in all provinces except the pooled model. In the pooled model, farmers' debt negatively affects efficiency. As in the case of debt, the case of having soil analysis in the farm was found significant only in the pooled model. It had soil analysis in the pooled model negatively affected efficiency. While the variable of irrigation number of apple lands was not significant for Isparta and Karaman provinces, it was statistically significant for the Niğde province and the pooled model. The increase in the number of irrigation in the province of Niğde has a positive effect on efficiency.

Table 4: Parameter estimates of the factors affecting the inefficiency of farms

	Isparta		Karaman		Niğde		Pooled	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Constant	2.590***	0.953	2.943***	1.133	-0.979	1.150	0.435***	0.137
Age (year)	-0.568*	0.306	0.231	0.293	0.646**	0.268	0.664	0.462
Education (year)	-0.675***	0.144	-0.726***	0.241	0.305*	0.171	-0.524***	0.136
Non-farm income (Dummy 1:yes)	0.135***	0.033	-0.205	0.085	-0.114	0.096	0.202***	0.068
Experience (year)	0.347**	0.142	-0.820***	0.199	-0.221**	0.097	-0.068	0.287
Farmers' debt (Dummy 1:yes)	-0.003	0.036	-0.028	0.048	0.008	0.060	0.139*	0.080
Have a soil analysis (Dummy 1:yes)	-0.069	0.047	-0.041	0.048	0.066	0.057	0.144**	0.067
Number of irrigation	0.020	0.0005	-0.045	0.114	-0.531***	0.112	-0.432***	0.061

*Denotes significance at 10%, **Denotes significance at 5%, ***Denotes significance at 1%.

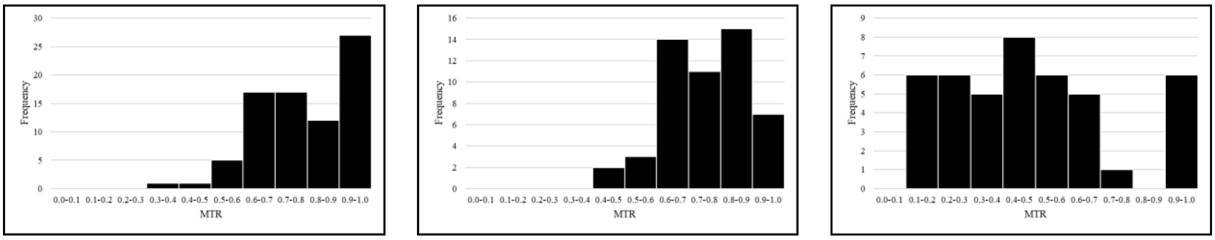
MTR is important in explaining farms' ability to compete with different groups in terms of production efficiency. This ratio estimates the technology gap used by farms in different regions with different combinations of input and output. MTR shows the extent to which the highest output in the provinces can be increased to reach the output given in the metafrontier using the existing input set. The higher the average value of MTR for a group, the more advanced its production technology (Battese et al., 2004).

In this study, the maximum likelihood estimates preferred for computing the provinces' stochastic frontiers were given in Table 5. Provincial-level efficiency scores, MTRs, and metafrontier technical efficiency scores were calculated for all farms. Summary statistics of these calculations can also be seen in Table 5. The mean values of MTR were found 0.80 in Isparta, 0.76 in Karaman, and 0.49 in Niğde. These results mean that apple farms for Isparta, Karaman, and Niğde, produce respectively about 80%, 76%, and 49% of the potential output given the level of technology available for the apple industry as a whole. Even though the data shows that MTR in Isparta province is higher than those of Karaman and Niğde, it shows that apple producers in all three provinces lack some technologies or do not adopt some technologies. The existence of farms in the metafrontier production frontier in all three provinces was noteworthy. The fact that the MTR was one indicated that it is tangent to the metafrontier. The distribution of MTRs of the provinces was presented in Figure 3. Results showed that the MTR values of apple farms in Isparta and Karaman provinces were above average, the MTR values of apple farms in Niğde were below average.

Table 5: Summary statistics of provincial-level efficiency scores, MTRs, and metafrontier technical efficiency scores

		Isparta	Karaman	Niğde	Pooled
Technical efficiency with respect to the group frontiers (TE^k)	Mean	0.780	0.811	0,766	0,628
	Standard deviation	0.183	0.179	0,170	0,229
	Minimum	0.387	0.304	0,397	0,126
	Maximum	1.000	1.000	0,991	0,989
Metatechnology ratio (MTR)	Mean	0.797	0.759	0.487	0.710
	Standard deviation	0.152	0.137	0.262	0.221
	Minimum	0.395	0.426	0.158	0.158
	Maximum	1.000	1.000	1.000	1.000
Technical efficiency with respect to the metafrontier (TE^*)	Mean	0.617	0.609	0.366	0.553
	Standard deviation	0.177	0.156	0.213	0.209
	Minimum	0.243	0.225	0.095	0.095
	Maximum	0.998	0.999	0.978	0.999

Relative to metafrontier, apple farms in Isparta province achieved the highest mean technical efficiency. On the other hand, the metafrontier technical efficiency of Karaman was close to Isparta, and the technical efficiency of Niğde was very low compared to the provinces of Isparta and Karaman. The technical efficiency of Karaman was the highest relative to the regional stochastic frontier, but the technical efficiency of the three provinces was found to be close to each other. When it comes to the potential output defined by the metafrontier function, Niğde was the furthest province.



a- Isparta b- Karaman c- Niğde

Figure 3. Distribution of MTRs of the provinces

5. Conclusion

This study aimed to compare apple farms' efficiency in Isparta, Karaman, and Niğde provinces in Turkey, which differ in terms of soil, climatic conditions, and production characteristics. It was determined that the efficiency of the apple farms differ by applying the stochastic metafrontier approach. The SFA results showed that the average efficiency score of the apple farms in Karaman province was higher than the provinces of Isparta and Niğde, but the MTR results showed that the apple farms in Isparta were closer to the metafrontier.

The efficiency analysis determined that apple farms in Isparta, Karaman, and Niğde provinces had high technical efficiency in their regional frontiers, but these efficiencies decreased in metafrontier analysis. This result shows that efficiency can be increased by changing the amount of input used in apple cultivation. In this respect, carrying out research activities to determine the amount of input to be used and transferring the obtained results to apple producers is of great importance.

Ensuring that the regional production frontier of Isparta, Karaman, and Niğde provinces approaches the metafrontier production frontier, it is necessary to carry out infrastructure, scientific and educational studies as a whole.

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8. Appendix

* The file parm.txt contains estimated parameters of group frontiers (by column)

* The file sfa#.txt contains n# data observations for group #

* Sections 1 and 3 are problem-specific.

* 1. SET NUMBERS OF PARAMETERS ETC.

gen1 nparms = 21

gen1 ngroups = 3

gen1 n1 = 80

gen1 n2 = 52

gen1 n3 = 43

* 2. READ THE ESTIMATED PARAMETERS OF THE GROUP FRONTIERS

smpl 1 nparms

```
read (parm.txt) parm / rows = nparms cols = ngroups

do # = 1,ngroups

  dim b# nparms

  copy parm b# / fcols=#;# tcols = 1;1

endo

* 3. READ THE DATA AND CONSTRUCT DATA MATRICES AND VECTORS

gen1 j2 = n1+1

gen1 j3 = n1+n2+1

gen1 k2=n1+n2

gen1 n  = n1+n2+n3

smpl 1 n

genr one = 1

read (sfa1.txt) group t ly lx1-lx5 lx11-lx15 lx22-lx25 lx33-lx35 lx44-lx45 lx55

smpl j2 k2

read (sfa2.txt) group t ly lx1-lx5 lx11-lx15 lx22-lx25 lx33-lx35 lx44-lx45 lx55

smpl j3 n

read (sfa3.txt) group t ly lx1-lx5 lx11-lx15 lx22-lx25 lx33-lx35 lx44-lx45 lx55

smpl 1 n

matrix x =
one|lx1|lx2|lx3|lx4|lx5|lx11|lx12|lx13|lx14|lx15|lx22|lx23|lx24|lx25|lx33|lx34|lx35|lx44|lx45|lx
55

dim x1 n1 nparms x2 n2 nparms x3 n3 nparms

copy x x1 / frows=1;n1  trows=1;n1

copy x x2 / frows=j2;k2 trows=1;n2

copy x x3 / frows=j3;n trows=1;n3

do # = 1,ngroups

  matrix yhat# = x#*b#

endo

matrix b = -(yhat1'|yhat2'|yhat3')'

* 4. OBTAIN AND PRINT PARAMETERS OF THE METAFRONTIER

stat x / means = xbar
```

```
matrix c = ((-xbar')|xbar')'

matrix A = (-x)|x

?lp c A b / iter = 5000 primal = bstar

dim beta1 nparms beta2 nparms

gen1 p1 = nparms+1

gen1 p2 = nparms*2

copy bstar beta1 / frows=1;nparms trows=1;nparms

copy bstar beta2 / frows=p1;p2 trows=1;nparms

matrix beta = beta1-beta2

print beta

* 5. OBTAIN AND PRINT TECHNOLOGY GAP RATIOS

do # = 1,ngroups

  matrix xbeta# = x#*beta

  matrix mtr# = exp(yhat#)/exp(xbeta#)

  stat mtr#

  print mtr#

endo

stop
```