Analysis of technical, allocative and economic efficiency in garlic production: the case of kastamonu province in Türkiye

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Abstract

This study aims to determine the efficiency values and socio-economic factors that cause inefficiency in garlic production. The study was conducted in Kastamonu, in the province of Türkiye, where the most garlic is produced. According to 2022 data, the share of Kastamonu province in Türkiye's garlic production area and production quantity is 23.61% and 21.01%, respectively. The study determined 59 enterprises producing garlic using a simple random sampling method, and a questionnaire survey was conducted. The data obtained by the face-to-face survey method were analysed using the Data Envelopment Method. Tobit's analysis also determined socio-economic factors causing inefficiency. Technical efficiency, pure technical efficiency, scale efficiency, allocation efficiency and economic efficiency values were calculated as 0.887, 0.962, 0.922, 0.490 and 0.436, respectively. These results show that enterprises producing garlic can obtain the same yield by using 11.3% fewer inputs and enterprises should reduce input costs by 56.4%. According to the results of the Tobit model, the factors that increase the efficiency of garlic production are that the garlic producer is young, the duration of his garlic experience is long, he has a non-agricultural income, his education level is high and the number of individuals in his household is low.

Keywords*:* Garlic, Technical efficiencies. Economic efficiencies. Allocative efficiencies. Data envelopment analysis. Tobit analysis.

1. Introduction

Garlic production in Türkiye is intensively carried out in certain provinces, but it is grown in almost all provinces. Kastamonu Province, the study region, ranks first in terms of production area and production quantity (TURKSTAT, 2023). Many farmers in this region make their living from garlic production. Taşköprü Garlic produced in Taşköprü district, where the research was conducted, received geographical indication from both the Turkish Patent and Trademark Office (15/06/2010) and the European Union (16/04/2021) (TURKISH PATENT, 2023; EU - DOOR, 2023). In this respect, Taşköprü Garlic has brand value and is an essential source of income for farmers.

The primary purpose of agricultural production is to increase the production amount and productivity of the enterprise by ensuring the most efficient and harmonious use of soil, climate, water, plant and labour resources according to the possibilities of agricultural enterprises. In this way, the income level of farmers will increase and farming enterprises will increase their contribution to national income. In every production activity, supplying the factors of production at the most economical price and utilising them at the optimum level affects both increasing productivity and reducing costs. Producers cannot utilise agricultural production factors at an optimum level due to inadequacies in their working capital and lack of technical knowledge. This situation negatively affects the product yield and, thus, the farmer's income (Gündoğmuş, 1997).

Efficiency shows the degree or distance of the inputs used in production from the targeted output. Efficiency studies are needed for the optimum utilisation of scarce resources in the agricultural sector, for more efficient farming enterprises and for comparing the targeted efficiency levels at the farming enterprise level (Kaçıra, 2007; Parlakay, 2011).

No study was found on garlic production's efficiency in Türkiye, our research area. In the literature, there are limited studies on the cost and profitability of garlic production (Gül et al., 2018; Kaplan et al., 2022). In addition, efficiency studies for crop and plant products other than garlic are common in Türkiye (Gül, 2005; Gül, 2006; Bozoğlu and Ceyhan, 2007; Gül et al., 2009; Parlakay and Alemdar, 2011; Gündüz et al., 2011; Gündüz et al., 2016; Bozdemir, 2017; Örmeci Kart et al., 2018; Kadakoğlu, 2021; Bayav, 2022; Kadakoğlu and Karlı, 2022; Subaşı et al., 2022). Our study aimed to determine the economic, technical, allocative, pure technical, and scale efficiency of garlic production in Kastamonu Province, an essential region in garlic production in Türkiye. In line with this, the study is important for Türkiye and the research region. The study results will benefit garlic producers, agricultural policymakers, relevant researchers and organizations.

2. Literature Review

Hussain et al. (2014) determined the technical efficiency of garlic cultivation in the Khyber Pakhtunkhwa province of Pakistan using the stochastic frontier analysis (SFA) method. The study's data were selected from 110 farmers by a multi-stage sampling method. Using the Cobb-Douglas production function, they found that the technical efficiency score ranged from 0.21 to 0.95, with an average of 0.775. They also determined that age and education were statistically significant ineffectiveness factors. They found that the increase in the farmer's age affects technical efficiency negatively and the increase in the education level affects technical efficiency positively.

Using the SFA method, Miraj and Ali (2014) determined the technical efficiency of garlic farms in Khyber Pakhtunkhwa, Peshawar district, Pakistan. The data were obtained from 110 garlic farmers selected using multistage sampling. They determined the average technical efficiency score for garlic producers to be 0.846. They determined the minimum efficiency score to be 0.576 and the maximum to be 0.961.

Sabzevari et al. (2015) calculated the energy efficiency of garlic producers in Guilan Province, Iran. They used the non-parametric data envelopment analysis (DEA) method as the analysis method. They obtained the data from 60 garlic farmers using the face-to-face survey method. As a result of the research, they calculated the average of the technical, pure technique and scale efficiency scores as 0.847, 0.940 and 0.896, respectively.

Wardani and Darwanto (2018) calculated the technical efficiency of garlic producers in the Temanggung region, the largest garlic-producing region in Central Java Province. The study's data were obtained by interviewing 60 garlic producers using a simple random sampling method. They used the SFA method to analyze the data. As a result of the research, they found that the technical efficiency score ranged between 0.287 and 0.811, with an average of 0.962. The socio-economic factors affecting technical inefficiency were determined as farmer age, number of workers in the family, farmer's education level and participation in farmer organizations. They determined that the increase in the farmer's age and the number of workers in the family would decrease the farm's technical efficiency. In contrast, the rise in farmer education and participation in farmer organizations will increase technical efficiency.

Rabbani and Ahmad (2021) determined garlic cultivation's technical, allocative and economic efficiency in Upazila of Dinajpur District of Bangladesh using the SFA method. The data were obtained through telephone interviews with 51 randomly selected garlic farmers. They determined that garlic producers' average technical, allocation and economic efficiency scores of 0.69, 0.82 and 0.57, respectively. They stated that the low-efficiency scores were due to the farm management and that the efficiency scores would increase with better farm management.

3. Materials and Methods

3.1. Materials

The primary material of this research was the data obtained by the face-to-face survey method from the producers in the villages producing garlic in the Taşköprü and Central districts of Kastamonu. Farm-level research data were collected from garlic farms using a well-designed questionnaire. The questionnaires were completed with the approval of the Ethics Committee at Isparta University of Applied Sciences, with a 14/06/2022 date and 112-03 number. Kastamonu Province has a 23.61% area of garlic production and 21.02% of garlic production in Türkiye. Taşköprü and Central district constitute 98.80% of the garlic production area and 99.17% of the garlic production quantity of Kastamonu province (TURKSTAT, 2023). In addition, secondary data for the study were obtained from national and international literature.

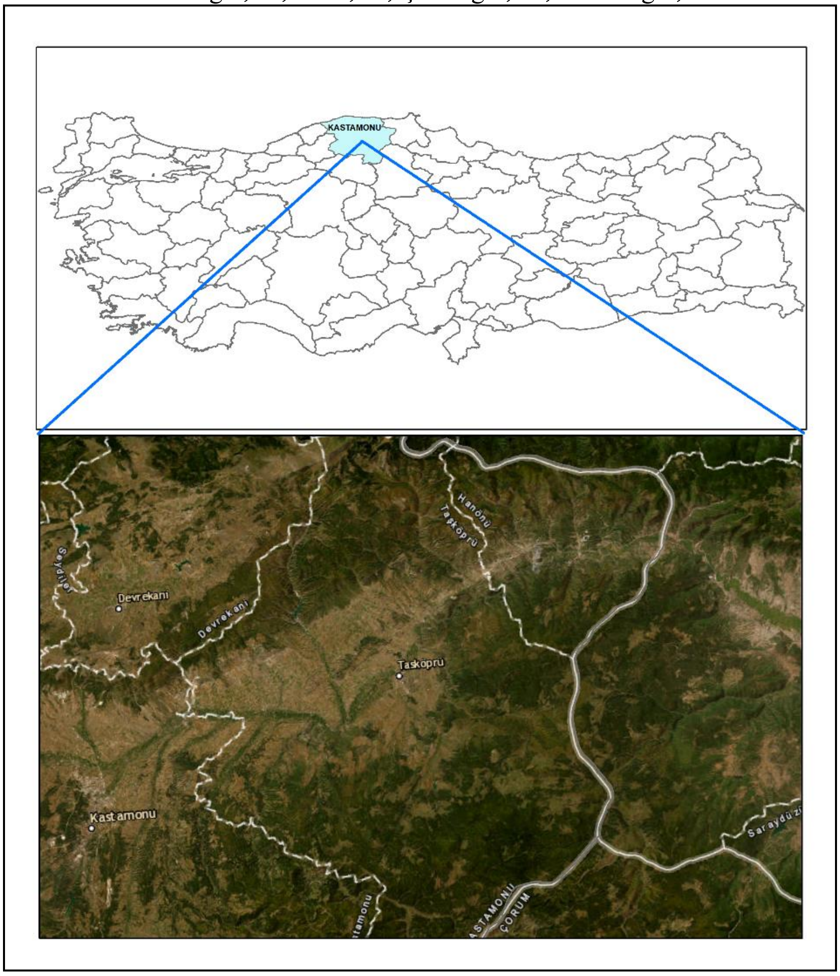

Figure 1: Research area

3.2. Methods

The number, land area and farm addresses of farms involved in garlic production were obtained from the Kastamonu Directorate of Provincial Agriculture and Forestry. Neyman Method was used to determine the sample volume of the survey (Yamane, 2001).

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

In equality;

n: Sample size,

N: Total number of units in the population,

N_h: Number of units in group h,

S_h: Standard deviation of group h,

S_h^2: Variance of group h,

D_2: d_2/z_2,

d_2: Allowed error from population average,

z_2: Value of the allowed safety limit in the distribution table.

The data were generated from statistics from 59 farms selected by stratified random sampling. Farm data were collected for the 2022 production period.

Efficiency measurement methods in the agricultural sector are divided into parametric and non-parametric methods for input and output. It is based on the aim of determining how much the amount of information can be reduced without any change in the current output amount in input-oriented measurements, and how much the output amount can be increased without any change in the current input amount in output-oriented measurements (Coelli et al., 2005). Stochastic Frontier Analysis (SFA) from parametric methods and Data Envelopment Analysis (DEA) from non-parametric methods are the two most commonly used approaches to measure efficiency (Kadakoğlu, 2021).

There are various calculation methods in the DEA method. In this study, the single output-multiple input DEA method was used. As dependent and independent variables, technical, allocation, pure technical, scale and economic efficiencies of garlic production were measured using the DEAP 2.1 program (Coelli, 1996). The model based on the assumption of constant returns to scale is given below (Coelli et al., 1998; Coelli et al., 2005);

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

limitations

$$-y\ i + Y\lambda \geq 0$$

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

$$\lambda \geq 0$$

In equality;

θ: is a scalar value, the ith enterprises efficiency value,

λ: a vector of size Nx1,

Y: output matrix,

X: represents the input matrix.

The efficiency scores of the enterprises are shown with a "θ" that takes a value between zero and one. This linear programming model needs to be solved separately for each enterprise. The economic efficiency measurement included the costs of all independent variables in the analysis.

The Tobit model determined various factors affecting technical and economic efficiency. Since the efficiency scores obtained from DEA analysis are between 0 and 1, the censored Tobit model was used (Greene, 2003).

$$u_i > -\beta_0 - \sum_{i=1}^{n} \beta_i X_i \text{ if } Y_{ij} = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + u_i$$

$$u_i < -\beta_0 - \sum \beta_i X_i \text{ if } Y_{ij} = 0$$

In equality;

Y_{ij}:is the technical and economic efficiency measure for the ith enterprise;

X_i: explanatory variables affecting efficiency;

N: is the number of explanatory variables;

β_i: model parameters;

u: is the error term.

4. Results and Discussion

In the DEA analysis and Tobit model, which are used to measure the efficiency of garlic farms in the region, some inputs are used extensively in production and significantly impact efficiency.

Input and statistics of variables causing inefficiency in garlic farming used in this study were summarized. The average garlic yield of 59 farms per hectare was 9755.93 kg. The lowest and highest yields per hectare were calculated as 3800.00 kg and 13000.00 kg, respectively. In garlic production, it was determined that an average of 1201.69 kg of seeds per hectare, 5775.26 kg of manure, 380.85 kg of chemical fertilizers, 5.04 hg of herbicide, 9.09 hg of fungicide, 1306.12 hours of labour, and 25.85 hours of machine power were used (Table 1).

The inefficiency variables depict that the average age of the farmers was approximately 45.90 years, with minimum and maximum periods of 28 and 68 years, respectively. Farmers' average garlic farming experience is about 29.47 years, minimum and maximum values are 10 and 55. It was determined that the farmers had a high garlic farming experience. In the enterprises, the answer was received as to whether the farms were indebted. The average indebtedness of enterprises is 1.42. On average, 6.03 people belong to a garlic grower's family. The average non-farm income in enterprises is 1.83. While no farmers were without formal education, they completed an average of 7.76 school years. The education level was grouped as primary and middle school (1), high school (2), and university (3). It was determined to be 1.39 on average. The education level of the farmers is close to the secondary school level (Table 1).

Table 1: Summary statistics for the variables used in the efficiency analysis and the Tobit model

Variables	Minimum	Maximum	Mean	Std. Deviation
DEA model				
Output				
Yield (kg/ha)	3800.00	13000.00	9755.93	1818.70
Inputs				
Area (ha)	0.20	5.50	1.61	1.21
Seed (kg/ha)	1000.00	1800.00	1201.69	243.88
Manure (kg/ha)	0.01	30000.00	5775.26	6631.22
Chemical fertilizer (kg/ha)	0.01	1350.00	380.85	323.74
Herbicide (hg/ha)	0.01	10.00	5.04	3.16
Fungicide (hg/ha)	0.01	220.00	9.09	28.59
Labour (h/ha)	225.03	4555.84	1306.12	919.55
Machine (h/ha)	13.33	40.00	25.85	5.85
Tobit model				
Age (year)	28.00	68.00	45.90	10.39
Experience in garlic production (year)	10.00	55.00	29.47	12.10
Farms debt (1:yes 2:no)	1.00	2.00	1.42	0.50
Family size (persons)	3.00	11.00	6.03	1.81
Non-farm income (1:yes 2:no)	1.00	2.00	1.83	0.38
Education level (1:primary and middle school 2:high school 3:university)	1.00	3.00	1.39	0.64

The technical, pure technical, scale, allocation and economic efficiency scores and frequency distribution (%) of farms for DEA methods are shown in Table 2.

The technical efficiency value of enterprises was found to be 88.7%. 1 farm with a TE score in the range of 0.41-0.50, 1 farm in the field of 0.51-0.60, 6 farms in the range of 0.61-0.70, 8 farms in the range of 0.71-0.80, 8 farms in the field of 0.81-0.90; and 9 farms in the range of 0.91-0.99. It was determined that 26 enterprises, 44.07% of the total enterprises, were fully productive. Enterprises will be able to obtain the same amount of output by reducing their inputs by an average of 21.3% and reducing their costs at this rate.

The pure technical efficiency value of enterprises was found to be 96.2%. 2 farms had PTE scores in the range of 0.61-0.70, 3 farms were in the field of 0.71-0.80, 4 farms were in the 0.81-0.90 range and 2 farms were in the range of 0.91-0.99. It was determined that 48 enterprises, 81.36% of the total enterprises, were fully productive.

The scale efficiency value of enterprises was found to be 92.2%. 1 farm with an SE score of 0.41-0.50, 3 farms in the field of 0.61-0.70, 3 farms in the 0.71-0.80 range, 8 farms in the 0.81-0.90 range and 17 farms in the range of 0.91-0.99. It was determined that 27 enterprises, 45.77% of the total enterprises, were fully productive.

The allocative efficiency value of enterprises was found to be 49%. 18 farms with AE scores in the range of 0.01-0.40, 15 farms in the field of 0.41-0.50, 11 farms in the range of

0.51-0.60, 6 farms in the 0.61-0.70, 5 farms in the 0.71-0.80, 2 farms in the field of 0.81-0.90, and 2 farms in the range of 0.91-0.99.

The economic efficiency value of enterprises was found to be 43.6%. 27 farms with EE scores in the range of 0.01-0.40, 13 farms in the field of 0.41-0.50, 9 farms in the range of 0.51-0.60, 4 farms in the 0.61-0.70, 3 farms in the 0.71-0.80, 1 farm in the field of 0.81-0.90, and 2 farms in the range of 0.91-0.99.

Table 2: Frequency distributions of efficiency scores obtained with DEA model

Efficiency score	Technical Efficiency (TE)	Pure Technical Efficiency (PTE)	Scale Efficiency (SE)	Allocative Efficiency (AE)	Economic Efficiency (EE)
	Farm (N)				
1.00	26	48	27	0	0
0.91-0.99	9	2	17	2	2
0.81-0.90	8	4	8	2	1
0.71-0.80	8	3	3	5	3
0.61-0.70	6	2	3	6	4
0.51-0.60	1	0	0	11	9
0.41-0.50	1	0	1	15	13
<0.41	0	0	0	18	27
	Percentage (%)				
1.00	44.07	81.36	45.77	0.00	0.00
0.91-0.99	15.26	3.39	28.82	3.39	3.39
0.81-0.90	13.56	6.78	13.56	3.39	1.69
0.71-0.80	13.56	5.08	5.08	8.47	5.08
0.61-0.70	10.17	3.39	5.08	10.17	6.78
0.51-0.60	1.69	0.00	0.00	18.64	15.26
0.41-0.50	1.69	0.00	1.69	25.42	22.03
<0.41	0.00	0.00	0.00	30.52	45.77
Minimum	0.471	0.667	0.471	0.102	0.098
Maximum	1.000	1.000	1.000	0.958	0.958
Mean	**0.887**	**0.962**	**0.922**	**0.490**	**0.436**
Std. Deviation	0.134	0.088	0.113	0.197	0.198

The overuse of all variables included in the efficiency analysis of the production process was determined. This overuse problem was detected in most farms. In the enterprises where these problems were observed, 25 of them were in land use (42.37%), 11 of them in seed use (18.64%), 25 of them in manure use (42.37%), 19 of them in chemical fertiliser use (32.20%), 18 of them in herbicide use (30.51%), 19 of them in fungicide use (32.20%), 25 of them in labour use, and 19 of them in machine power use (32.20%). Fungicide was used at the highest rate, with an excess of 146.4%. The rest is labour (81.23%), chemical fertilizer (78.11%), manure (71.17%), herbicide (46.07%), farm size (44.18%), machine power (30.72%) and seeds (22.07%) (Table 3).

Table 3: Farms' using input slacks and excessive inputs

Inputs	Number of farms	Mean input usage	Mean input slack	Excessive input usage (%)
Area (ha)	25	1.61	0.71	44.18
Seed (kg/ha)	11	1201.69	265.23	22.07
Manure (kg/ha)	25	5775.26	4110.11	71.17
Chemical fertilizer (kg/ha)	19	380.85	297.49	78.11
Herbicide (hg/ha)	18	5.04	2.32	46.07
Fungicide (hg/ha)	19	9.09	13.31	146.45
Labour (h/ha)	25	1306.12	1060.95	81.23
Machine (h/ha)	19	25.85	7.94	30.72

ha: hectare, kg: kilogram, hg: hectogram, h: hour

The relationship between socio-economic variables and efficiency scores (TE and EE) in garlic farming was determined by the Tobit model. Tobit's model contained the following variables: farmer age, experience in garlic production, farm debt, family size, non-farm income, and education level.

The coefficient for farmer age has a negative coefficient, indicating that the younger the farmer, the higher the technical efficiency. A 1% decrease in farmer age increases the technical efficiency value by 0.005668, with all other factors remaining constant. The value coefficient is statistically significant at 5% ($p<0.05$).

The coefficient for our garlic production experience is positively consistent with our expectations and statistically significant at 5%. A unit increase in the experience ratio in garlic production would cause an increase in technical efficiency value by 0.004297, all other variables in the model constant. The higher the expertise of farmers for the product, the higher the predicted efficiency value.

The coefficient for non-farm income has a positive coefficient, indicating that the higher the non-farm income, the higher the technical efficiency. A 1% increase in non-farm revenue increases the technical efficiency value by 0.089487, with all other factors remaining constant. The value coefficient is statistically significant at 5% ($p<0.05$).

The coefficient for education level is positively consistent with our expectation and statistically significant at 10%. A unit increase in the ratio of education level in farmers would lead to an increase in technical efficiency value by 0.052178, all other variables in the model constant. The higher the education level of farmers, the higher the estimated efficiency value.

The coefficient for farmer age has a negative coefficient, indicating that the younger the farmer, the higher the economic efficiency. A 1% decrease in farmer age increases the technical efficiency value by 0.0063, with all other factors remaining constant. The value coefficient is statistically significant at 10% (p<0.10). It was determined that the younger age of the farmer increased both the technical and economic efficiency values.

The coefficient for experience in garlic production has a positive coefficient, indicating that the higher the experience in garlic production, the higher the economic efficiency. A 1% increase in non-farm income increases the economic efficiency value by 0.005392, with all other factors remaining constant. The value coefficient is statistically significant at 10% (p<0.10).

The coefficient for family size is negative, indicating that the smaller the family, the higher the economic efficiency. A 1% decrease in farmer age increases the economic efficiency value by 0.028561, with all other factors remaining constant. The value coefficient is statistically significant at 5% (p<0.05). This result showed that household populations need to be used more effectively in garlic production. An increase in the number of households reduces economic efficiency.

Table 4: The parameters and their standard errors of Tobit model

Variable	Coeff.	Std. Err.	z-score	Sig.	Coeff.	Std. Err.	z-score	Sig.
Efficiency value	TE				EE			
Constant (c)	0.861	0.150	5.743	0.000***	0.723	0.222	3.256	0.001***
Age	-0.006	0.002	-2.359	0.018**	-0.006	0.004	-1.771	0.077*
Experience in garlic production	0.004	0.002	1.982	0.048**	0.005	0.003	1.679	0.093*
Farms debt	-0.022	0.035	-0.635	0.526	0.061	0.052	1.180	0.238
Family size	-0.008	0.009	-0.842	0.400	-0.029	0.013	-2.156	0.031**
Non-farm income	0.089	0.042	2.110	0.035**	-0.018	0.063	-0.281	0.779
Education level	0.052	0.029	1.775	0.076*	-0.027	0.044	-0.626	0.531
R-squared	0.180				0.170			
Adjusted R-squared	0.067				0.056			

*** Significant at 1%, ** Significant at 5%, * Significant at 10% level of statistical

In our study, we determined the factors that increase efficiency in garlic production are that the garlic producer is young, the farmer's education level is high, and the number of individuals in the farmer's household is low. Similar results are also found in Hussain et al.'s (2014) and Wardani and Darwanto's (2018) studies.

5. Conclusions and Recommendations

This study, which measures garlic enterprises' technical, allocation, scale, pure technical and economic efficiency, an essential product for Turkish agriculture, and determines the socio-economic variables that cause inefficiency, is necessary for farmers and agricultural policymakers. According to the study results, the average technical efficiency score was 0.887, the average pure technical efficiency score was 0.962, the average scale efficiency score was 0.922, the average allocation efficiency score was 0.490, and the average economic efficiency score was 0.436. The technical efficiency result shows garlic enterprises can obtain the same yield using 11.3% fewer inputs. The economic efficiency result shows that enterprises should reduce their input costs by 56.4%. Thus, garlic enterprises will produce with optimal input composition by reducing their resources to the minimum price.

There was a statistically significant negative relationship between farmer age and the technical efficiency score ($p<0.05$) and economic efficiency score ($p<0.10$). There is a statistically significant positive relationship between garlic production experience and technical efficiency score ($p<0.05$) and economic efficiency score ($p<0.10$). There was a statistically significant positive relationship between the technical efficiency score and non-agricultural income ($p<0.05$) and farmer education level ($p<0.10$). A statistically significant negative relationship exists between the economic efficiency score and family size ($p<0.05$). The factors that increased efficiency were determined to be the youngness of the garlic producer, the duration of garlic experience, having a non-agricultural income, having a high level of farmer's education and having a low number of individuals in the farmer's household.

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