Economic and Technical Efficiency of Tomato crop Production in Nineveh Governorate, Iraq: for the Season Production 2025

Saad Talal Mustafa Aswan Abdel Qader Zeidan
College of Agriculture and Forestry, University of Mosul
Corresponding Author ; email : saad.25agp8@student.uomosul.edu.iq

Abstract

This research aims to achieve a number of objectives that collectively form the policy of agriculture related to measuring economic efficiency (EE). The technical efficiency of the tomato crop in Nineveh Governorate was estimated and analyzed using the SFA random frontier analysis method based on the transcendental logarithmic production function. This was achieved by focusing on the basic inputs used in the research, namely the total quantity of seeds, human labor, number of hours of mechanized operation, total quantity of chemical fertilizer, number of irrigations, and total quantity of pesticide. The average was found based on estimates of technical efficiency and numerical values of explanatory parameters of the superior logarithmic production function using three methods: ordinary least squares (OLS), corrected least squares (COLS), and the maximum likelihood method. The Deep Data Envelopment program was used to determine economic efficiency in its two components (technical and functional efficiency). The results of the economic efficiency estimation for the tomato crop showed that the farms that achieved the highest efficiency value (100%) were the same farms that achieved full functional efficiency, totaling (5) farms, equivalent to (8.3%) of the sample farms. The lowest economic efficiency value was at farm number (28), reaching (59%). Therefore, this farm must reduce its production inputs by approximately (41%) to achieve optimal economic efficiency. The average economic efficiency achieved was 80.6%, compared to technical efficiency is considered low. Which is refers those farmers may be able to reduce costs by 19.4% while maintaining the same level of production. Furthermore, it was observed that the farms which achieved the best results with the lowest input costs are simultaneously those that attained both technical efficiency and allocative efficiency. These farms fall within the constraints of the ISO project curve; therefore, it is essential that they adhere to the same production method. The amount of resources achieved for economic efficiency per dunam was estimated by assuming a change in returns to scale (VRS) for the farms in the study sample, specifically for the main study variables, based on the Data Envelopment Analysis (DEAP) method according to the cost function, and by estimating the quantity of resources at the lowest cost at which economic efficiency is achieved. The average scale efficiency of the sample farms was 0.942, ranging from a high value of 100% to a low value of 0.729. This indicates a potential increase in agricultural production by 38% while maintaining the same level of resources used."

This means there is a surplus of this percentage, as (15) farms achieved a full volumetric efficiency of (100%) and constituted (25%) of the total sample. As for the volumetric efficiency of (90-99%), it was achieved by (31) farms, constituting (51.6%) of the sample. A number of conclusions were reached, including that the efficiency of tomato production in Nineveh Governorate for the 2025 season is average to good technically, but it is below the optimal level economically due to climate challenges, costs, and weak marketing infrastructure. Therefore, the study recommends encouraging farmers to make optimal use of agricultural areas by cultivating tomatoes and some other crops by providing seeds, fertilizers, pesticides, and other production inputs to farmers at nominal prices.

ISSN 2072-3857

Keywords: Economic and scale efficiency, DEAP data envelope analysis program, Superior Logarithmic Production Function (SFA)
Keywords: Tomato production, data envelopment, technical efficiency, agricultural resource

1.Introduction:

Tomatoes are among the most strategic vegetable crops in Iraq, particularly within the Nineveh Governorate, playing a fundamental role in enhancing food security and generating significant economic returns for local farmers. The 2025 agricultural season in Nineveh witnessed a substantial expansion in tomato cultivation, driven by favorable climatic conditions, highly fertile soils in regions such as Rabia, Qayyarah, and Rashidiya, alongside the accumulated expertise of local producers. This season was characterized by an unprecedented production boom, resulting in a massive daily influx of thousands of tons into local wholesale markets, such as the Rabia wholesale market. Consequently, this surge in supply relative to domestic demand led to a sharp decline in market prices. While this abundant harvest underscores Nineveh's capacity to effectively supply major markets across Iraqi governorates—including Baghdad—it also aligns with national agricultural policies aimed at achieving self-sufficiency and restricting unregulated imports. However, despite this production success, farmers faced severe economic hurdles, primarily due to structural marketing bottlenecks and a lack of agro-processing facilities, such as tomato paste factories, which drastically eroded profit margins. This critical gap emphasizes the urgent need to optimize agricultural supply chains and value-added processing systems to ensure sectoral sustainability.

In the context of empirical literature, Shams and Girgis (2015) conducted an economic assessment of tomato production technologies under plastic tunnels in Ismailia Governorate. Their study aimed to identify optimal input combinations and determine actual, optimal, and economic production volumes. The findings indicated that human labor, mechanization, and various fertilizers (potassium, phosphate, organic, and nitrogen) were the primary drivers of output, placing production within the economically rational second stage of the classical production function. Allocative efficiencies were remarkably high for nitrogen and organic fertilizers, yielding a return of 57 piasters per invested currency unit. The actual output (16.5 tons/feddan) fell within the optimal (15.4 tons) and economic (17 tons) thresholds.

Furthermore, Zaitoun et al. (2020) evaluated the resource-use efficiency of tomato production, addressing the instability of total production value during the period (2003–2018). Utilizing descriptive and quantitative economic criteria, including allocative and economic efficiency indicators, they found that both summer and winter tomato cycles are heavily labor-intensive. In Minya Governorate, the winter cycle exhibited superior economic performance, characterized by higher net revenues and lower overall production costs. The study emphasized the necessity of revitalizing agricultural extension services to curb resource dissipation.

More recently, Al-Dulaimi (2024) estimated the economic efficiency of tomato cultivation in the Rabia district of Nineveh Governorate for the 2024 season. Utilizing a structured questionnaire to survey a random sample of 61 farms (representing 27% of the total 225 farm population), the study employed Data Envelopment Analysis (DEA) via the DEAP software. Under the assumption of Variable Returns to Scale (VRS), the mean technical, allocative (specialized), and economic efficiencies were estimated at 0.948, 0.860, and 0.816, respectively. The study concluded that significant resource misallocation and waste persist among local producers, driving them away from cost-minimizing output levels. This is further supported by recent empirical findings in the region, which highlight how structural market failures and resource misallocations continue to hinder the economic potential of vegetable cultivation in Northern Iraq (Ahmed & Hassan, 2025; Al-Ubaidi & Al-Mola, 2024; Al-Amri & Al-Khafaji, 2025).

1.1Search problem:

The core research problem lies in a structural economic paradox within Nineveh Governorate's agricultural sector. On one hand, the province achieves an abundant production surplus during peak harvest windows (such as the 2025 season); on the other hand, this seasonal glut triggers severe marketing bottlenecks and price collapses due to a lack of refrigerated storage and processing infrastructures (Al-Jahiashi, 2023). This market saturation drives wholesale prices below the total cost of production, inflicting heavy losses on local farmers and discouraging future cultivation. Conversely, during off-peak periods, the local market suffers from supply deficits, opening the gateway for cheaper foreign imports that aggressively compete with the domestic product in terms of price and quality. Compounding this issue, many local producers still rely on conventional, sub-optimal management practices, leading to substantial resource misallocation and diminished economic efficiency.

Therefore, the research problem can be articulated through the following question:

"Does the production efficiency of tomato cultivation in Nineveh Governorate achieve optimal resource allocation that guarantees rewarding economic returns for farmers, or do structural bottlenecks and resource waste restrict the sector's capacity to capitalize on its high yields?"

1.2 Research objectives:

The primary objective of this study is to evaluate the production efficiency of tomato crops in Nineveh Governorate for the 2025 season, identify the key institutional and economic determinants affecting it, and establish the levels of technical and allocative efficiency. To achieve this, the following sub-objectives are addressed:

1. To measure the total production and productivity per unit area (dunam) across the surveyed farms.
2. To estimate technical, allocative, and economic efficiencies using an input-oriented Data Envelopment Analysis (DEA) model under both Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) frameworks.
3. To determine the optimal resource combinations required to achieve economic efficiency and cost minimization per dunam under VRS.
4. To formulate realistic, data-driven recommendations aimed at mitigating marketing risks and enhancing resource-use efficiency.

1.3 Research Hypothesis:

This study operates on the hypothesis that the majority of tomato producers in Nineveh Governorate have not yet attained cost-minimizing production scales or optimal land allocation, primarily due to volatile market dynamics that compel many to downscale operations. Furthermore, it is hypothesized that limited technical knowledge regarding optimal input combinations and modern agricultural innovations hinders farmers from achieving maximum physical output at the lowest feasible economic cost.

1.4 Importance of the Research:

ISSN 2072-3857

The significance of this research stems from its empirical approach to addressing food security and economic stability in Nineveh Governorate and Iraq as a whole. By assessing the efficiency of critical inputs (land, water, and labor), this study provides policy-makers with empirical indicators necessary for formulating protective agricultural and marketing strategies. Additionally, it offers actionable insights for local producers to optimize their resource allocation, minimize production costs, and overcome structural marketing constraints.

2.Materials and Methods:

-Describing the Economic Efficiency Measurement Model through:

Data Collection and Variables Description

This study employs a descriptive and quantitative analytical approach to evaluate the production and economic efficiency of open-field tomato cultivation in Nineveh Governorate for the 2025 agricultural season.

Sampling Design: Primary empirical data were collected using a structured questionnaire specifically designed for this study. The sample comprises a random selection of 60 tomato farms distributed across the primary production zones of the governorate.

Model Variables: The empirical analysis incorporates total tomato production (Y, measured in kg/dunam) as the dependent output variable. The independent input variables (productive resources) include: total quantity of seeds (X_1), human labor (X_2, hours/dunam), mechanized labor (X_3, hours/dunam), total chemical fertilizer applied (X_4, kg/dunam), irrigation frequency (X_5, number of irrigations), and total chemical pesticides used (X_6).

Analytical Framework: The data were analyzed using a two-stage approach: first, a Stochastic Frontier Analysis (SFA) was applied to estimate a Transcendental Logarithmic (Translog) production function using Frontier software to establish technical efficiency. Second, a non-parametric Data Envelopment Analysis (DEA) was executed via DEAP software to estimate allocative and economic efficiencies under the assumption of Variable Returns to Scale (VRS).

- Data Envelopment Analysis Model under the Variable Returns to Scale (VRS) Assumption:

The assumption of constant returns to scale is only applicable when all farms operate at their optimal size. In reality, however, many obstacles prevent farms from achieving these sizes, including imperfect competition and financing constraints. The constant returns to scale assumption are used in the Data Envelopment Analysis (DEA) model when not all farms or establishments operate at their optimal size. This results in a mix of technical and scale efficiency indicators. To separate the effects of technology and scale on efficiency measurement, the VRS model developed by Fraser and Cording (1999) is used. The CRS model is modified into the VRS model in the linear programming problem by adding the size constraint of 1; it takes the following form:

$$Min_{\theta,\lambda}\theta^{VRS} \dots\dots\dots\dots\dots\dots\dots (1)$$

The data envelopment analysis model with an input-oriented approach is illustrated in Figure 1. Linear programming aims to minimize the input vector of farms or facilities (Xi) proportionally while maintaining the possibility of achieving the output level I, which is consistent with Farrell's theorem. Figure 1 represents the projected points AO and OB onto the vector curve. This illustrates the possibility of minimizing the input vector Xi while aligning it with the broken production Isoquant curve.

ISSN 2072-3857

SS = production Isoquant curve.
Points C and D show how well two technically efficient facilities worked. They define the inner frame of the SS curve. Points A and B represent the performance of two facilities that are technically inefficient. A and B represent the points on the SS curve that correspond to points A and B.
The technical efficiency of facility B is calculated as and that of point A as B n the SS curve.

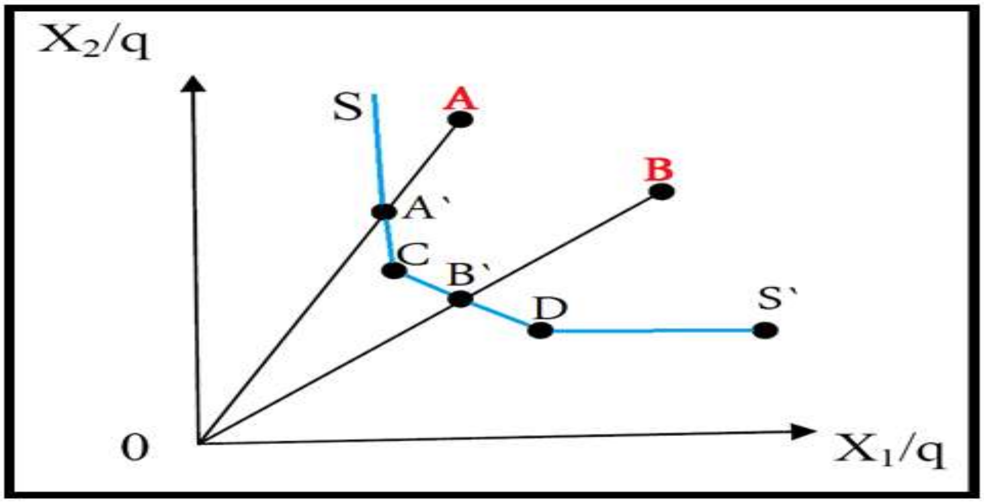

Figure (1) Economic Efficiency (Coelli, 1996:13)

The technical efficiency of facility B is calculated as and that of point A as. Note that the proposed point lies between points C and D on the SS curve. However, the use of input X2 can be reduced without reducing the output Y. Therefore, the efficiency of points projected onto the horizontal or vertical segments of the SS curve is questionable. This is due to the use of linear segmentation to obtain the SS curve. The increased use of X2 is known as input slack, and this occurs in the outputs and is called output slack (Coelli, 1996: 13).

The DEAP model is used when a farm's goal is to produce as much as possible while keeping a certain amount of input. This is done by using efficiency measurement models that focus on output. The farm's technical efficiency rate, using the output model, is defined as the proportional increase in production while keeping inputs constant at a specific level.
Output-oriented Data Envelopment Analysis (DEA) models are quite similar to input-oriented models. The following model demonstrates this similarity, assuming variations in returns to scale under the output-oriented approach:

$$Max_{\theta,\lambda}\theta - - - - - - - - - - - - - (2)$$

The DEAP model, which is designed to produce specific results, can be illustrated as shown in Figure 2. This figure shows the outer frame of the linear segmentation of the production potential curve. Obviously, points P and Q are not very efficient, while point A is efficient. It is also clear that point P' is on the technical efficiency curve. We can increase the production level of commodity Q1 by AP' without increasing the use of inputs.

The output-oriented DEAP model can be illustrated as shown in Figure (2). This figure represents the outer frame of the

ISSN 2072-3857

linear segmentation of the production possibility curve. It's clear that points P and Q are not very efficient, but point A is efficient. It is also clear that, although point P' lies on the technical efficiency curve, we can increase the production level of good Q1 by the amount AP' without increasing the use of inputs (Coelli & Battese, 2005: 367).

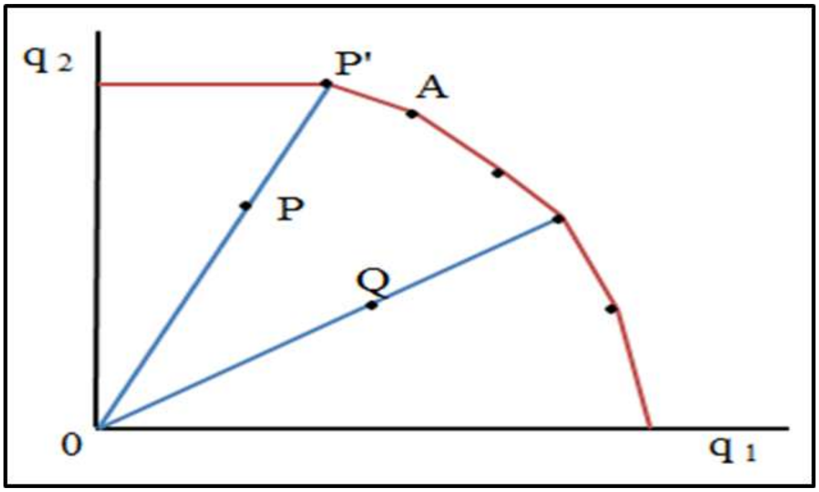

Figure (2) The DEAP model shows how to use economic efficiency from the output side. (Coelli & Battese, 2005, 187)

Since the models of use-oriented and output-oriented work to estimate technical limits, there is no disagreement between them in characterize the fully efficient facilities. However, the difference lies in the calculation of the efficiency index for technically inefficient enterprises when the economies of scale are not constant (Babiker, 2002: 25). From an applied perspective, the choice between use-oriented and output-oriented data envelope analysis models when measuring efficiency rates depends on the degree to which the facilities have control over the determination of production inputs and outputs." (Al-Mashhadani, 2021: 68).

3.Results and Discussion:

First: Results of estimating the economic efficiency of tomato farmers in the 2025 production season study sample for using the random frontier analysis method based on the transcendental logarithmic function:

We used a method called "Stochastic Frontier Analysis" to estimate and analyze the technical efficiency of tomato production in Nineveh Governorate. This method is based on a specific type of production function called the "transcendental logarithmic function". We estimated technical efficiency (TE) using the stochastic frontier approach. We focused on the main inputs used in the study. These inputs include the total quantity of seeds, human labor, number of mechanical working hours, total amount of chemical fertilizers, number of irrigation operations, and total quantity of pesticides used. The average was determined using three methods: Ordinary Least Squares (OLS), Corrected Ordinary Least Squares (COLS), and Maximum Likelihood Estimation

(MLE). The results were then checked to make sure they were correct.

Table (1). Table (1) Values of the explanatory variables' parameters for the tomato crop in Nineveh Governorate for the superior logarithmic production function

Variable	Parameter	Parameter estimation using the OLS	method; Parameter estimation after correction (COLS);	Parameter estimation using the (ml) method;
	B_0 T	(- 0.12) - (0.776)	- (0.12)	– 0.17 -0.51
Total quantity of seeds	B_1 T	0.72 0.24	0.72	0.72 70.2
Human labor	B_2 T	7.63 1.63	1.63	1.63 1.90
Number of working hours	B_3 T	-1.83 -1.811	-1.83	1.81 1.10
Total quantity of chemical fertilizer	B_4 T	2.100 1.71	2.10	2.10 2.12
Number of irrigations	B_5 T	0.80 0.60	0.80	0.78 0.32
Total quantity of pesticide	B_6 T	1.82 1.71	1.82	1.11 1.22

Likelihood function = (0.62)

The following table illustrates the values of the production function parameters and the Translog, as determined by the OLS method. Following the implementation of the necessary corrections, the values are calculated to reach the value of ml. This will be used to interpret the relationship between the independent variables in the function, specifically the quantity of production (the dependent variable). The findings indicate that the parameters of the variables (total quantity of seeds, mechanized labor) and the total quantity of chemical fertilizer (number of irrigations, total quantity of fertilizer) are consistent with the logic of economic theory, thereby confirming the positive impact of these variables on the quantity of production. Therefore, a 1% increase in the explanatory variable results in an increase in production equal to the elasticity of that variable. However, the variable of the number of automated working hours contradicts the logic of economic theory, thereby confirming the negative impact of this variable on production. In other words, an increase in the explanatory variable by 1% results in a decrease in the quantity of production by a percentage equal to the value of the elasticity of this variable. The subsequent discussion will provide an elucidation of these variables.

1.Seed quantity: - The t-test showed that this variable was not significant compared to the tabulated t of 1.70. Therefore, this variable had a positive relationship with the quantity of production, as its elasticity value was 0.24. An increase in the quantity of seeds by 1% leads to an increase in the quantity of production by 0.24%. This indicates that the effect of the quantity of seeds on production is limited because farmers have reached the common plant density. Therefore, the

ISSN 2072-3857

increase in production is limited and not clear despite the positive trend, and the lack of significance is due to farmers adopting uniform or recommended seeding rates.

Human labor: The analysis revealed the significance of this variable through the t-test compared to the tabulated t of 1.70, and its elasticity value was approximately 1.63 provides evidence of a positive relationship between human labor and the quantity of production. An increase in human labor of 1% leads to an increase in the quantity of production of 1.63. This is consistent with economic theory, and the reason for this is that tomatoes are crops that require continuous care (service, weeding, pruning, irrigation) and monitoring of pests and diseases, and a light touch in harvesting operations.

2.Human labor: The analysis revealed the significance of this variable through the t-test compared to the tabulated t of 1.70, and its elasticity value was approximately 1.63 provides evidence of a positive relationship between human labor and the quantity of production. An increase in human labor of 1% leads to an increase in the quantity of production of 1.63. This is consistent with economic theory, and the reason for this is that tomatoes are crops that require continuous care (service, weeding, pruning, irrigation) and monitoring of pests and diseases, and a light touch in harvesting operations.

3.Number of hours of mechanized work: The analysis showed the significance of these two variables in the t-test compared to the tabulated t of 1.70, and its elasticity value was approximately 1.811, indicating the negative relationship between mechanized work and the quantity of production. An increase in mechanized work of 1% leads to a decrease in the quantity of production of 1.83. This is contrary to economic theory, and the reason for this is due to the unsuitability of machines for energy crops, because some operations (such as planting, ploughing, harvesting) require precision that machines do not provide. The inappropriate use of machines may lead to damage to roots or plants and breakage of branches and flowers. The repeated use of plowing or mechanized hoeing reduces soil fertility and negatively affects production. Therefore, pruning, pest control, and harvesting are more efficient with human labor.

Total amount of chemical fertilizer: The analysis showed the significance of this variable through the t-test compared to the tabulated t of 1.70, and its elasticity value was about 2.100, indicating the existence of a positive relationship between this variable and the quantity of production. The reason for this is that tomatoes are crops that are highly responsive to fertilization, especially nitrogen (N) for vegetative growth, phosphorus (P) for root and flower development, and potassium (K) for improving fruit set and quality. This indicates that this element represents one of the main determinants of production, and increasing its use within appropriate rich levels leads to an increase in the quantity of production and improved productivity as a result of the crop's high response to basic nutrients.

4.Total amount of chemical fertilizer: The analysis showed the significance of this variable through the t-test compared to the tabulated t of 1.70, and its elasticity value was about 2.100, indicating the existence of a positive relationship between this variable and the quantity of production. The reason for this is that tomatoes are crops that are highly responsive to fertilization, especially nitrogen (N) for vegetative growth, phosphorus (P) for root and flower development, and potassium (K) for improving fruit set and quality. This

ISSN 2072-3857

indicates that this element represents one of the main determinants of production, and increasing its use within appropriate rich levels leads to an increase in the quantity of production and improved productivity as a result of the crop's high response to basic nutrients.

5.Number of irrigations: The analysis revealed that this variable was not significant using the t-test, compared to the critical t-value of 1.70. Its elasticity value was 0.80, indicating a positive relationship between this variable and the quantity of production. This suggests that the positive effect is not statistically sufficient to prove that the number of irrigations is an independent factor affecting production. This is due to several reasons, including the similarity in the number of irrigations among the farmers in the sample, which reduces the variance and thus the effect does not appear significant. Additionally, the irrigation used was sufficient, as the crop reached the stage of water saturation, and any increase in the number of irrigations would not lead to a noticeable increase in production, Likewise, the adequacy of the irrigation used means that the crop has reached the stage of water saturation, and any increase in the number of irrigations does not lead to a tangible increase in production. In addition, there are also factors affecting the crop, including soil quality, fertilization, pesticides used, and the variety planted, which affect the number of irrigations. Finally, the interference of the number of irrigations with other variables in the statistical model (a serious multiple correlation problem) all these factors affect the insignificance of this variable.

Total pesticide quantity: The analysis showed the significance of this variable through the t-test compared to the tabulated t of 1.70, and its elasticity value was about 1.82, indicating the existence of a positive relationship between this variable and the quantity of production. The reason for this is that pesticides have a real and confirmed effect on the quantity of tomato production and not a random effect, and that tomatoes are crops that are very sensitive to infestation by pests and diseases (insect, fungal, viral).

The proper use of pesticides leads to a reduction in crop loss, protection of flowers and fruits from damage, and improvement of fruit set and growth. Positive sentiment indicates that farmers who use pesticides regularly and appropriately achieve higher production levels. The rational use of pesticides contributes to reducing losses and improving crop productivity, thus increasing the quantity of production.

The logarithmic function for maximum probability reached a positive value of (0.62), indicating that there are technological changes that positively affect the random variable and, consequently, the technical efficiency of farms (1-60) cultivating tomatoes.

The values of the transcendental logarithmic production function, whose parameters were estimated using the estimation methods (OLS, COLS, mL), will be used to estimate the technical efficiency (TE) of the indicated farms using the Stochastic Folder Analysis (SFA) method and the Frontier software.

The technical efficiency values of the farms were estimated according to the random bounds method (SFA) and fixed in Table (2). It is evident that the levels of technical efficiency (TE) reached between a minimum of (0.60) for farm (3) and a maximum of (1.000) for farms (42, 41, 38, 34, 33, 9, 54, 52), which indicates a deviation of production from the production possibilities of these farms. The average efficiency for the farms reached (0.829). This result for the level of technical efficiency of the tomato

ISSN 2072-3857

crop indicates that the number of farmers is able to produce the same output with fewer resources equivalent to (82%) of the resources used, which indicates a deviation of actual production from optimal production by (18%), as shown in Table (2).

Table (2) Results of estimating the technical efficiency (TE) of the tomato crop in Nineveh Governorate according to the production function (TL) using the random bounds method (SFA)

Farms	**Technical Efficiency (TE)**	**Farms**	**Technical Efficiency (TE)**
1	0.85	31	0.80
2	0.78	32	0.94
3	0.60	33	1.000
4	0.80	34	1.000
5	0.74	35	0.76
6	0.92	36	0.66
7	0.88	37	0.94
8	0.87	38	1.000
9	1.00	39	0.63
10	0.85	40	0.85
11	0.75	41	1.000
12	0.76	42	1.000
13	0.78	43	0.82
14	0.69	44	0.87
15	0.86	45	0.96
16	0.80	46	0.73
17	0.93	47	0.79
18	0.93	48	0.76
19	0.88	49	0.74
20	0.83	50	0.80
21	0.71	51	0.74
22	0.76	52	1.000
23	0.69	53	0.77
24	0.71	54	1.000
25	0.95	55	0.72
26	0.74	56	0.76
27	0.81	57	0.73
28	0.81	58	0.74
29	0.79	59	0.86
30	0.87	60	0.97

Reference: prepared by the researcher based on the outputs of the Frontier statistical program.

Secondly: Results of estimating the economic efficiency, with its two components (technical efficiency and specialized efficiency), of tomato farms in Nineveh Governorate in the study

ISSN 2072-3857

sample for the (2025) production season, using the Deep Envelopment Analysis method according to the cost function variables:

The economic efficiency (EE) for the tomato farms in the study sample for the 2025 production season was estimated using Deep Data Analysis (DDA). This efficiency was separated into two parts: technical efficiency (TE) and specialty efficiency (AE). The cost function variables, resource quantities, and prices were used to estimate the efficiency. It was assumed that returns to scale varied. The results of the estimated economic efficiency (EE), technical efficiency (TE), and specialty efficiency (AE) levels are shown in Table (3). Twenty-seven farms were found to have achieved the highest possible efficiency (100%), which is 45% of the maximum possible efficiency. These farms were able to produce the most tomatoes while using only a few inputs. So, these farms are on the isotropic production curve. This means they should keep using the same methods to take care of their resources and stay productive. The lowest efficiency was seen at farms 1, 5, 22, and 26, reaching about 92%. These farms should produce the same number of tomatoes as before, but use 92% less water and other resources. This means that they would only need to use a very small amount of the resources they use now to get the best results. On average, farmers were 97.6% efficient, meaning they could use 3% less of their production inputs to achieve the same level of production.

The following section will examine the specialization efficiency (SE) of the tomato farms in the study sample. The SE of the farms was estimated based on the prices of the resources used. As shown in Table 3, five farms, representing 8.3% of the sample, achieved the highest efficiency value. This percentage is low compared to the percentage of farms achieving technical efficiency. This phenomenon contributes to the limited number of farms that attain economic efficiency. The lowest value for specialized efficiency was observed at farm number 28, which reached 62%. Consequently, this farm must curtail production inputs by approximately 38% of production costs while preserving the production quantity to attain optimal specialized efficiency. Concurrently, the mean specialized efficiency attained approximately 82.5%. Consequently, the farms within this sample are required to curtail expenditures by 17.5% by utilizing a maximum of 82% of inputs while sustaining equivalent crop yields. The Economic Efficiency (EE) was subsequently calculated by multiplying the TE and AE results for each farm.In consideration of economic efficiency (EE), it is noteworthy that the number of farms attaining the maximum efficiency value (100%) is equivalent to the number of farms achieving full specialized efficiency, amounting to five farms. This is equivalent to 8.3% of the sample farms. Notably, farm number 28 exhibited the lowest economic efficiency, with a value of 59%. Consequently, it is imperative for this farm to curtail its production inputs by approximately (41%) to attain optimal economic efficiency. The average economic efficiency achieved was 80.6%, which is regarded as low in comparison to the mean values of technical efficiency. This suggests that farmers may be able to reduce costs by 19.4% while maintaining the same level of production. Furthermore, the number of farms that attained optimal outcomes with a minimal input expenditure is congruent with those that simultaneously achieved technical efficiency and specialized efficiency. These farms are also confined to the limits of the is project curve. Consequently, it is imperative that production be maintained in accordance with the established methodology.The results presented in Table (3) indicate that the levels of economic and specialization efficiency were low compared to the levels of technical efficiency in the farms included in the study sample. This is attributed to the realities of the agricultural sector in Iraq in general, and in Nineveh Governorate in particular, especially the lack of government support and the high costs of agricultural production, particularly pesticides, fertilizers, machinery, and even labor, which are significant, especially at the beginning of the production season. Furthermore, the optimal quantities of seeds, fertilizers, and pesticides are not being used.

Table (3): Estimation of Technical and Specialization Efficiency under Changes in Return on Capacity in the Farms of the Research Sample

Economic Efficiency)EE(	Aloctive Efficiency AE)(	Technical Efficiency)TE(	Number of Farmer
0.772	0.831	0.929	1
0.73	0.734	0.994	2
0.63	0.66	0.95	3
0.74	0.74	1.00	4
0.68	0.74	0.920	5
0.96	0.96	1.00	6
0.88	0.89	0.98	7
0.92	0.92	1.00	8
0.82	0.85	0.97	9
0.76	0.76	1.00	10
0.75	0.75	1.00	11
0.80	0.80	1.00	12
0.80	0.83	0.97	13
0.69	0.72	0.96	14
0.96	0.96	1.00	15
0.84	0.84	1.00	16
0.87	0.89	0.97	17
0.92	0.92	1.00	18
0.88	0.88	1.00	19
0.88	0.881	1.00	20
0.79	0.83	0.95	21
0.71	0.77	0.92	22
0.65	0.65	1.00	23
1.00	1.00	1.00	24
0.76	0.81	0.94	25
0.85	0.92	0.92	26
0.81	0.85	0.95	27
0.59	0.62	0.93	28
0.85	0.92	0.93	29
0.86	0.92	0.94	30
0.73	0.76	0.96	31
0.83	0.83	1.00	32

ISSN 2072-3857

1.00	1.00	1.00	33
1.00	1.00	1.00	34
0.78	0.78	1.00	35
0.63	0.66	0.95	36
0.86	0.86	1.00	37
0.86	0.89	0.96	38
0.74	0.78	0.95	39
0.71	0.74	0.96	40
0.70	0.72	0.97	41
0.70	0.76	1.00	42
0.76	0.76	0.99	43
0.81	0.85	0.95	44
0.81	0.87	0.94	45
0.79	0.82	0.95	46
0.74	0.75	0.98	47
0.75	0.75	1.00	48
0.74	0.77	0.96	49
0.66	0.66	1.00	50
0.74	0.78	0.94	51
1.00	1.00	1.00	52
0.71	0.74	0.95	53
0.82	0.82	1.00	54
0.77	0.77	1.00	55
0.80	0.80	1.00	56
0.83	0.85	0.97	57
0.73	0.75	0.96	58
0.73	0.73	1.00	59
1.00	1.00	1.00	60
0.80	0.82	0.97	Average
0.63	0.65	0.92	Lowest value
1.00	1.00	1.00	Highest value

Reference: Prepared by the researcher based on questionnaire data using the Deep Data

8.Encryption Program

The results in Table (4) indicate that the number of farms whose production lies at the point of tangent to the cost line and within the is producible was (5), constituting (8.3%) of the total number of farms in the research sample. These farms are considered to have achieved economic efficiency (100%). The number of farms that ranged between (100-80) was (26) farms, constituting a percentage estimated at (43.6%). The number of farms achieving economic efficiency that fall between (80-60) farms was (28) farms, constituting a percentage of (46.6%). As for the farms achieving economic efficiency that fall between (60-40) farms, it was (1) farm, constituting a percentage of (1.66%), The results indicate that farm number (28)

ISSN 2072-3857

achieved the lowest economic efficiency, with a percentage of (59%). This means that the percentage of loss in economic resources reached (41%). This is a reasonable percentage, but this farm should be reconsidered in order to be a filter for the other farms. This can be explained through Table (4), which shows the levels of economic efficiency and its components according to the cost function, the number of farms, and their percentages from the total study sample.

Table (4) Economic efficiency levels and their components according to the cost function, the number of farms and their percentages of the total study sample

Economic Efficiency)EE(		**Allocative Efficiency)AE(**		**Technical Efficiency) TE(**		**Level of Efficiency**
%	Number of Farms %	**%**	Number of Farms %	**%**	Number of Farms %	
8.3	5	8.3	5	45	27	100
43.6	26	48.3	29	55	33	80 -100
46.6	28	43.3	26	-	-	60 – 80
1.6	1	-	-	-	-	40 – 60
100	60	100	60	100	60	the total

Reference: Compiled by the researcher based on the results of the analysis of Table (3)

Third: Results of the scale efficiency assessment for tomato farms in Nineveh Governorate in the study sample for the 2025 production season:

Scale efficiency simply means the extent to which a production unit (farm) can operate at the optimal production size that achieves the lowest possible cost and highest possible output.

It is the ratio of technical efficiency under constant yields of scale (CRS) to technical efficiency under variable yields of scale (VRS), i.e., SE = TECRS/TEVRS. If scale efficiency = 1, this means that the farm is operating at the optimal size (scale efficient). DEAP analysis reveals three cases:

1. Increasing Returns to Scale (IRS): This means the farm is smaller than its optimal size, and increasing inputs leads to a larger increase in output. Therefore, the farm needs to expand production to reach the optimal level of output and achieve a scale efficiency of one.

2. Constant Returns to Scale (CRS): This means the farm is operating at its optimal size and is in the best economic and productive position. It achieves constant returns to scale and zero economies of scale.

3. Decreasing Returns to Scale (DRS): This means the farm is operating larger than its optimal size, meaning there are no economies of scale, and increasing inputs is not matched by a similar increase in output. Therefore, the farm suffers from over-investment or poor organization and must reconsider its combination of resources and output (Al-Mashhadani, 2021: 201). Regarding the tomato crop, the estimation results were as follows:

Table (5) shows that the average volumetric efficiency of the sample farms was (0.942), ranging from a high of (100%) to a low of (0.729). This indicates the potential for increasing farm production by (38%) at the same level of resource usage. This means there is a surplus of this percentage, as (15) farms achieved full volumetric efficiency of (100%), representing (25%) of the total sample. (31) farms achieved volumetric efficiency of (90-99%), representing (51.6%) of the sample, while (9) farms achieved volumetric efficiency of (80-89%), representing (15%) (5) farms achieved a scale efficiency of (70-79%) to constitute (8.3%), and it was found that (45) farms operate under increasing returns to scale IRS and (15) farms operate under stable scale CRS and there is no farm operating in the case of decreasing returns to scale DRS. The explanation for this is that most of the production units operate below the optimal economic size and that increasing inputs will lead to an increase in output by a greater percentage, which means that expanding agricultural activity will improve scale efficiency and productivity, The absence of diminishing returns to scale is explained by the fact that the units have not reached the stage of overexpansion, and there are no acute problems resulting from large size or administrative complexity. The agricultural sector does not suffer from production inflation, but on the contrary, it is still in a stage where production gains can be achieved through well-considered expansion. As for the explanation of fixed returns to scale (CRS) units, it is explained by the fact that these farms operate within the optimal size for production and do not suffer from waste or a shortage of resources.

Table (5) Results of estimating technical efficiency and scale efficiency assuming constant and variable yields per unit area

Yield per unit area	**% TE Case of VRS**	**%TE Case of CRS**	**% SE** Scale efficiency	**Frame**
Irs	0.928	0.871	0.938	1
Irs	0.999	0.993	0.999	2
Irs	0.958	0.698	0.729	3
Irs	0.983	0.934	0.949	4
Irs	0.939	0.812	0.865	5
Crs	1.000	1.000	1.000	6
Irs	0.981	0.921	0.939	7
Crs	1.000	1.000	1.000	8
Crs	1.000	1.000	1.000	9
Crs	1.000	1.000	1.000	10
Irs	1.000	0.839	0.839	11
Irs	1.000	0.950	0.950	12
Irs	0.968	0.929	0.959	13
Irs	0.961	0.931	0.969	14
Crs	1.000	1.000	1.000	15
Irs	I,000	0.999	0,999	16
Irs	0.974	0.966	0.992	17
Crs	1.000	1.000	1.000	18
Crs	1.000	1.000	1.000	19
Crs	1.000	1.000	1.000	20
Irs	0.958	0.717	0.748	21

ISSN 2072-3857

Irs	0.920	0.796	0.865	22
Irs	0.920	0.720	0.783	23
Irs	1.000	0.966	0.966	24
Crs	1.000	1.000	1,000	25
Irs	0.920	0.857	0.931	26
Irs	0.958	0.815	0.851	27
Irs	0.938	0.928	0.990	28
Irs	0.932	0,820	0.879	29
Irs	0.942	0,930	0.987	30
Irs	0.965	0.893	0.926	31
Crs	1,000	1.000	1.000	32
Crs	1.000	1.000	1.000	33
Crs	1.000	1.000	1.000	34
Irs	1.000	0.884	0.884	35
Irs	0.964	0.745	0.773	36
Irs	1.000	0.983	0.983	37
Irs	0.956	0.938	0.981	38
Irs	0.960	0.701	0.730	39
Irs	0.981	0.933	0.952	40
Irs	1.000	0.997	0.997	41
Irs	1.000	0.989	0.989	42
Irs	0.991	0.885	0.893	43
Irs	0.950	0.918	0.966	44
Crs	0.969	0.969	1.000	45
Irs	0.959	0.887	0.925	46
Irs	0.946	0.900	0.951	47
Irs	1.000	0.957	0.957	48
Irs	0.960	0.841	0.876	49
Irs	1.000	0.991	0.991	50
Irs	0.945	0.846	0.895	51
Crs	1.000	1.000	1.000	52
Irs	0.953	0.927	0.973	53
Crs	1.000	1.000	1.000	54
Irs	0.996	0.897	0.900	55
Irs	1.000	0.966	0.966	56
Irs	0.977	0.907	0.928	57
Irs	0.965	0.919	0.952	58
Irs	1.000	0.981	0.981	59
Irs	1.000	0.995	0.995	60
	0.977	0.921	0.942	Average
	100	100	100	Highest value
	0.920	0.698	0.729	Lowest value

ISSN 2072-3857

Reference: Prepared by the researcher using a questionnaire administered through the DEAP data encapsulation program.

3.1.Conclusions:

1. The efficiency of tomato production in Nineveh Governorate for the 2025 season demonstrated moderate-to-good technical performance. However, it remained significantly below the optimal economic frontier due to structural marketing bottlenecks, high input costs, and inadequate post-harvest infrastructure.
2. Empirical estimation of the economic efficiency (EE) under the Variable Returns to Scale (VRS) framework yielded an average score of *0.806. This implies that through the optimal reallocation of production inputs, local farmers could potentially reduce aggregate production costs by **19.4%* while maintaining their current output levels, or alternatively, maximize physical yields using their existing resource base.
3. The allocative (specialized) efficiency analysis revealed an average score of *0.825* across the surveyed sample. This indicates an economic waste of *17.5%* in the utilization of actual production resources. This allocative distortion is primarily driven by the absence of government subsidies on essential inputs, which forces farmers to purchase production factors at volatile open-market prices, leading to sub-optimal resource combinations.
4. The mean scale efficiency (SE) of the surveyed farms was estimated at *0.942, ranging between a fully efficient maximum of **1.00* and a minimum of *0.729. The results show that **15 farms* achieved absolute scale efficiency (representing *25%* of the total sample). For the inefficient units, optimizing the operational scale could enhance productivity by *38%* under current resource constraints, indicating substantial capacity underutilization in the region.

3.2 Recommendations:

1. *Institutional Subsidies for Production Inputs:* The Ministry of Agriculture should design target-oriented subsidy programs providing high-yield seeds, specialized fertilizers, and eco-friendly chemical pesticides at subsidized prices to mitigate the rising financial burden on local producers and lower the total cost of production.
2. *Enhancing Agricultural Extension and Resource Optimization:* Agricultural extension centers in Nineveh Governorate must be revitalized to provide data-driven guidance on optimal resource combinations. Training programs should focus on training farmers to eliminate the *17.5% allocative waste* by adopting modern agricultural innovations, precise fertilization schedules, and calculated irrigation practices.
3. *Strategic Import Regulation and Market Protection:* To counter the seasonal price collapses during peak harvest periods, strict seasonal tariff barriers and import quotas must be enforced. Preventing the market dumping of foreign tomatoes during peak domestic supply windows is vital to stabilizing local wholesale prices and

ISSN 2072-3857

securing sustainable profit margins for local farmers.

4. *Developing Post-Harvest Infrastructure and Agro-Industries:* Government and private investments should be channeled into establishing agro-processing plants (such as tomato paste and canning factories) within Nineveh Governorate. Additionally, establishing a network of refrigerated assembly centers would absorb the seasonal supply surplus during peak production, create value-added opportunities, and safeguard farmers against volatile price shocks.

4. References

1. Ahmed, M. S., & Hassan, F. Y. (2025).* Measuring technical and allocative efficiency of open-field tomato farms using Data Envelopment Analysis (DEA) in Nineveh Governorate. Mesopotamia Journal of Agriculture, 53(2), 112-127.
2. Al-Amri, M. K., & Al-Khafaji, A. H. (2025).* Measuring capacity efficiency and economic efficiency for tomato farmers using Data Envelopment Analysis (DEA): An applied study in Iraq. Iraqi Journal of Agricultural Sciences, 56(2), 420-435.
3. Al-Dulaimi, A. T. T. M. M. (2024).*The economic basis for tomato production in Nineveh Governorate: Implementation of production 2024 through Rabia models* (Master’s thesis). College of Agriculture, University of Mosul. https://uomosul.edu.iq/agriculture (uomosul.edu.iq in Bing)
4. Al-Dulaimi, Ammar Rabee Sheet. (2024).* Estimating the economic efficiency of tomato production in Nineveh Governorate for the 2024 production season: Rabi'a District as a case study. Rafidain Development Journal, 43(141), 115-132.
5. Al-Juhayshi, Khalid Ahmed. (2023).* Marketing bottlenecks and their impact on price stability of strategic crops in Nineveh Governorate. Sustainable Agricultural Sciences Journal, Light, 19(3), 89-104.
6. Al-Ubaidi, T. M., & Al-Mola, S. A. (2024).* Economic efficiency and resource misallocation in vegetable production: A case study of tomato cultivation in Northern Iraq. Iraqi Journal of Market Research and Consumer Protection, 16(1), 75-88.
7. Coelli, T. J. (1996).Aguide to Frontier Version 4.1 : A computer program for frontier production function estimation (CEP Working paper;No.96/07)/ Department of Econometrics, University of New England, Armidale, Australia. p. 5.https://une.edu.au/econometrics (une.edu.au in Bing).
8. Coelli, T. J., Rao, D. S. P., & Battese, G. E. (2005).*An introduction to efficiency and productivity analysis* (2nd ed.). Springer Science & Business Media. https://doi.org/10.1007/978-0-387-24265-1 (doi.org in Bing)
9. Fraser, I., & Cordina, D. (1999). Application of data envelopment analysis to an irrigated dairy farm in Northern Victoria, Australia. *Farming Systems*, 59. https://doi.org/10.1016/S0167-8809(99)00045-X (doi.org in Bing)

ISSN 2072-3857

10. Mashhadani, A. H. A. (2023). *Olive production measures in Nineveh Governorate: in Nineveh Governorate: Implementation of production 2021 (regarding monitoring an applied model)* (Master's thesis). College of Agriculture and Forestry, Tikrit University. https://tu.edu.iq/agriculture (tu.edu.iq in Bing)
11. Shams, S. S. E., & Girgis, M. R. (2015). An economic study of tomato production technology in Ismailia Governorate . *Egyptian Journal of Agricultural Economics*, 25(3), September. Suez Canal University. https://ejae.journals.ekb.eg (ejae.journals.ekb.eg in Bing)
12. Zeitoun, A. D. E., Badawi, S. E. H., & Mahmoud, I. I. (2020). Efficiency of agricultural resource use in tomato production. *Journal of Agricultural Economics and Social Sciences*, 11, 785–789. Department of Agricultural Economics, Faculty of Agriculture, Minia University. https://jaess.journals.ekb.eg (jaess.journals.ekb.eg in Bing)