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Profitability and Profit Efficiency in Wheat Farming: A Stochastic Frontier Analysis in Nineveh Governorate

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Abstract: This research examines the capacity of contemporary technologies to improve both profitability and profit efficiency for wheat farmers in the Nineveh Governorate. Utilizing the stochastic profit frontier model through Frontier 4.1 software, we assess the profit frontier alongside the inefficiency function. The maximum likelihood estimation highlights the influence of technological and managerial elements on the economic performance of agriculture. Key production inputs analyzed include output prices, land rental costs, pesticide expenditures, labor hours (both manual and mechanical), water consumption, seed costs, and fertilizer expenses. The results indicate that profitability is positively affected by higher output prices, land rents, labor input, and water consumption, whereas rising prices for pesticides and seeds negatively impact profitability. Additionally, the study investigates the influence of managerial factors—such as family size, education, irrigation experience, and the age of the farmer—on production inefficiency. Findings reveal that larger family sizes and more extensive farming experience contribute to a reduction in inefficiency. In contrast, increased levels of education, particular irrigation experience, and an older age of the farmer correlate with heightened inefficiency. This underscores the importance of integrating modern technologies with effective human resource management to optimize profitability. In conclusion, the study confirms that adopting modern technologies alongside improved agricultural management practices is crucial for sustainable profitability. We recommend reassessing production volumes, optimizing land use, strategically organizing labor with technology, and embracing advanced irrigation systems. Additionally, the study emphasizes the need for credit support and training programs to equip farmers with the skills and tools necessary to manage rising production costs and enhance resource management, ultimately contributing to improved economic performance in the agricultural sector. There are studies estimating technical efficiency for different crops and measuring the impact of modern irrigation systems on economic and production efficiency.

Keywords: Stochastic Profit Frontier, Efficiency Evaluation, Wheat Farmers

This is an adaptation of the abstract from the first researcher's doctoral thesis.

INTRODUCTION

In an era characterized by rapid technological advancements and evolving economic landscapes, identifying effective strategies to support agriculture and enhance its profitability is paramount. This study explores the potential of modern technologies to improve profitability and assess profit efficiency among wheat farmers in Nineveh Governorate, utilizing the stochastic profit frontier model. Corn is also considered one of the most important strategic crops. Our research focuses on estimating two key functions: the profit frontier, representing the maximum potential profit achievable with available resources, and the inefficiency function, quantifying deviations from this optimum. Utilizing maximum likelihood estimation through Frontier 4.1 software, we present a comprehensive analysis of

the correlation between technological factors and overall productivity in farming. The importance of this study is underscored by its investigation into how the integration of contemporary technologies can improve the economic efficiency of the agricultural industry.

In an era marked by rising production costs and the effects of climate change, these measurement tools provide valuable insights into the strengths and weaknesses of resource utilization. Such insights are crucial for shaping policies that seek to enhance the efficiency of resource investments while fostering sustainable profitability. This research examines the potential ramifications of not fully leveraging modern technologies within agricultural systems. Wheat farmers face profit efficiency challenges stemming from various factors, including family size, educational background, irrigation experience, and overall agricultural expertise, all of which can impact economic outcomes in both favorable and unfavorable manners. Consequently, a comprehensive analysis of these relationships is vital for offering practical recommendations aimed at improving the management of agricultural enterprises (Khan et al., 2018:115-132).

The objective of this study is to assess the impact of technological advancements and managerial factors on profit efficiency among wheat farmers in Nineveh Governorate. Through the estimation of parameters within the stochastic profit frontier model and the examination of inefficiency indicators utilizing Frontier 4.1 software, this research provides an in-depth analysis of how contemporary technologies can enhance economic performance, while also identifying elements that constrain profitability. Such an analysis empowers decision-makers to adopt more effective strategies for the agricultural sector (Hamad & Shabib, 2025:2).

The research hypothesis suggests that there exists a statistically significant correlation between technological factors—specifically family size, educational attainment, irrigation experience, and overall agricultural experience—and the inefficiencies identified in the profit frontier of wheat farmers. The theoretical framework evaluates the null hypothesis, which claims that no such relationship exists, in contrast to the alternative hypothesis that indicates modern technologies directly improve efficiency and profitability. By employing statistical analysis through Frontier 4.1, the study seeks to support the alternative hypothesis with robust empirical evidence (Miguel & Smith, 2019:892-907).

The profit frontier is specified by the following equation:

$$\text{Ln}\pi i = \text{Ln}\ \boldsymbol{\beta}o + \boldsymbol{\beta}1\ \text{Ln}\ y1 + \boldsymbol{\beta}2\ \text{Ln}\ X2 + \boldsymbol{\beta}3\ \text{Ln}\ X3 + \boldsymbol{\beta}4\ \text{Ln}\ X4 + \boldsymbol{\beta}5\ \text{Ln}\ X5 + \boldsymbol{\beta}6\ \text{Ln}\ X6 + \boldsymbol{\beta}7\ \text{Ln}\ X7 + \boldsymbol{\beta}8$$

$$\text{Ln}\ X8 + Vi - Ui$$

where:

$\boldsymbol{\pi}$: Profit (expressed as thousands of dinars per dunam).

(y_1): Output in kilograms per dunam.

(X1) to (X8): Independent variables defined as follows:

- X_1: Land rent (per dunam)

- X_2: Pesticide price (per liter)
- X_3: Price of human labor (per hour)
- X_4: Price of mechanized labor (per hour)
- X_5: Price of water usage (per cubic meter)
- X_6: Price of seeds (per kilogram)
- X_7: Price of fertilizers (per kilogram)

To assess how these technological variables influence efficiency, the model relies on the maximum likelihood (ML) method. Since these factors are viewed as key contributors to inefficiency, their corresponding coefficients—unknown parameters (for example, (\beta_0, \beta_1, \beta_2, \ldots, \beta_8))—are estimated from sample data collected within the study area. This approach is detailed in the work of (Suzuki and Nakamura ,2020:231–245).

The inefficiency component is defined by the following equation:

$$U_{it}=D_0+D_1Z_1+D_2Z_2+D_3Z_3+D_4Z_4+D_5Z_5$$

where:

(D1) to (D5): Parameters of the inefficiency model to be estimated.

(Z1) to (Z5): Managerial variables, defined as follows:

(Z_1): Family size (count).

(Z_2): Educational level, expressed as: 1: Illiterate,2: Primary,3: Middle,4: Preparatory,5: College

(Z_3): Experience in supplementary irrigation (years).

(Z_4): Age of the farmer (years).

(Z_5): Agricultural experience (years).

Using Frontier 4.1 software, the following steps were taken to obtain the parameters for the stochastic profit frontier function, assess profit efficiency, and estimate the parameters of the inefficiency variables (Ali, 2017:913–1001):

1. **Step A:** The estimation process began with the application of the Ordinary Least Squares (OLS) technique to obtain the best linear unbiased estimates of the production function's parameters, excluding the intercept term (B_0), which is recognized to be biased under this method.

2. **Step B:** To correct for the bias inherent in the intercept, the analysis proceeded with the Corrected Ordinary Least Squares (COLS) approach, which enables the derivation of unbiased parameter estimates, including the intercept.

3. **Step C:** Finally, the maximum likelihood (ML) method was utilized to calculate the maximum likelihood estimates for the parameters of the stochastic profit frontier function based on the superior logarithmic profit function.

Table (1) presents the results of the superior logarithmic profit function (TL) along with the inefficiency model for fixed irrigation.

Parameter	coefficient	standard-error	t-ratio
beta 0	3.366	0.996	3.378 ***
beta 1	0.734	0.0428	17.148 ***
beta 2	0.364	0.110	3.296 ***
beta 3	-0.068	0.0293	-2.331***
beta 4	0.205	0.0354	5.802 ***
beta 5	0.0195	0.0428	0.456
beta 6	0.356	0.0597	5.957 ***
beta 7	-0.206	0.0453	-4.547***
beta 8	-0.0207	0.0556	-0.373
delta 0	-10.202	5.7436	-1.776 **
delta 1	-0.215	0.0923	-2.329 **
delta 2	0.211	0.138	1.5217 *
delta 3	0.0418	0.0267	1.5624 *
delta 4	0.1236	0.0617	2.0017 **
delta 5	-0.0323	0.0221	-1.463 *
sigma-squared	0.24	1.217	2.047 **
gamma	0.98	0.0086	113.81 ***
log likelihood function	-138.625		

Source: Researcher's own work using Frontier 4.1

*Significant at the 10% level, ** Significant at the 5% level ,*** Significant at the 1% level

A. The estimated sigma squared (2σ) value is 0.24 and was statistically significant at the 0.05 level. This significance confirms that the assumed distribution for the composite error term is both appropriate and accurate.

B. With a gamma (Γ) value of 0.98—statistically significant at the 0.01 level—the study indicates that nearly 98% of the deviation from the profit frontier is due to inefficiency rather than random error. In simple terms, almost all the observed production variations are explained by profit inefficiency influenced by the technological variables examined.

C. The one-sided logarithmic error ratio (LR) test produced a value of 99.901, which is statistically significant at both the 0.01 and 0.05 levels. This result far exceeds the chi-square

critical values of 18.475 and 14.067, thereby supporting the alternative hypothesis. In other words, there is a significant relationship between the technological characteristics of farms—such as family size, educational level, supplementary irrigation experience, farmer's age, and crop cultivation experience—and profit frontier inefficiency. As a result, the null hypothesis, which claims that no such relationship exists, is rejected.

A. Profit Function Parameters:

The results indicate that key variables—including output price, land cost, labor hours, and water consumption—have a statistically significant and positive effect on agricultural profitability. A 1% increase in each of these inputs corresponds to profit gains of roughly 0.734%, 0.364%, 0.205%, and 0.356%, respectively. These findings highlight the economic importance of these factors in influencing farm-level financial performance.

From an economic perspective, the positive impact of output prices implies that increasing production is directly linked to higher profits. Similarly, higher land prices correlate with enhanced profitability—possibly reflecting supportive government policies that favor crops like wheat, thereby encouraging the expansion of cultivation and driving up land demand even as prices rise. The positive coefficient for human labor hours suggests that the seasonal peaks in wheat production, combined with limited rural labor availability, contribute to higher wages during busy periods. For water usage, factors such as reduced rainfall may force farmers to rely more on irrigation, leading to increased water costs.

Conversely, the coefficients for pesticide and seed prices are statistically significant but negative. This means that a 1% increase in pesticide and seed prices is associated with a decline in profits by 0.068% and 0.206%, respectively. Moreover, the coefficients for machinery and fertilizer prices did not show statistical significance.

B. Parameter Estimates for the Profit Inefficiency Model:

1. **Family Size (D1):** The model shows a statistically significant negative coefficient for family size, indicating that as the size of the family increases, profit inefficiency decreases.

2. **Level of Education (D2):** The analysis reveals a statistically significant positive coefficient for educational level. This finding, which appears counterintuitive, may suggest a discrepancy between formal education and the practical knowledge required for effective farm management, or it could reflect a rapid adoption of new technologies without adequate training. Certain studies indicate that there is a necessity for policies aimed at enhancing education in order to boost profit efficiency..

3. **Experience in Supplementary Irrigation (D3):** A coefficient that is both positive and statistically significant regarding supplementary irrigation experience indicates that an increase in experience in this domain is likely to lead to greater profit inefficiency. This phenomenon may stem from the persistence of suboptimal irrigation methods or an excessive dependence on irrigation.

4. **Age of the Farmer (D4):** The positive relationship between age and profit inefficiency, which is statistically significant, indicates that inefficiency tends to rise as

farmers grow older. This phenomenon may be associated with a slower rate of adopting new technologies or a reluctance to modify established farming practices..

5. **Crop Cultivation Experience (D5):** In contrast, the coefficient for general crop cultivation experience is negative and statistically significant, implying that more experience in cultivating crops overall is linked to *lower* levels of profit inefficiency. This aligns with the idea that practical experience contributes to better decision-making. Proper agricultural extension services could improve the efficiency of producers. It is important to consider that farmers may be too proud to adopt new practices, so framing is important when sharing information.

C- Profit Efficiency Results and Their Analysis for Fixed Irrigation Wheat Farmers

1- Profit Efficiency Results of Wheat Farmers by Household Size

Reviewing the estimated profit efficiency of wheat farmers with a household size of 1–6 members reveals an average efficiency of 0.69. This indicates that, for wheat farmers to operate efficiently, they must either increase their profits by 31% while maintaining current price and productivity levels, or adjust the price–productivity mix such that a 31% increase in productivity is achieved under the same efficiency level. In comparing the actual profits—amounting to 527,928 dinars per donum—with the estimated marginal profits of 748,434 dinars per donum, a profit loss of 220,506 dinars per donum due to inefficiency is evident. Furthermore, 20% of the farmers achieved profit efficiency below 50%, 16% attained efficiency in the range of 0.51–0.69, and the remaining 64% achieved efficiency between 0.70 and 0.99.

For wheat farmers with a household size of 7–20 members, the average profit efficiency was found to be 0.73. This implies that to achieve efficiency, these farmers must increase their profits by 27% while keeping prices and productivity constant, or modify the price–productivity balance to secure a 27% increase in productivity at this efficiency level. Comparing the actual profits of 501,499 dinars per donum with the estimated marginal profits of 672,831 dinars per donum shows a loss of 171,332 dinars per donum attributable to inefficiency. In this group, 13% of farmers recorded profit efficiencies of less than 50%, 14% achieved profit efficiency between 0.51 and 0.69, while the remaining 73% achieved efficiencies within the range of 0.70 to 0.99.

Table (2): Relationship Between Household Size and Profit Efficiency (Households 1–6) Under Fixed Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
220,506	748,434	527,928	0.69	

Table (3): Relationship Between Household Size and Profit Efficiency (7–20) Under Fixed Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
171332	672831	501499	0.73	

2- Profit Efficiency Results for Wheat Farmers by Educational Level

Reviewing the estimated profit efficiency of wheat farmers based on their educational level (illiterate) reveals an average efficiency of 0.75. This indicates that for wheat farmers to operate efficiently, their profits must increase by 25% while maintaining current price and productivity levels—or alternatively, prices and productivity must be adjusted so that overall productivity increases by 25% at this level of efficiency. A comparison between the actual profit of 460,189 dinars per donum and the estimated marginal profit of 615,614 dinars per donum shows a profit loss due to inefficiency amounting to 155,425 dinars per donum. Additionally, 9% of the farmers achieved a profit efficiency of less than 50%, 31% attained profit efficiency in the range of 0.51–0.69, while the remaining 78% of wheat farmers achieved efficiency levels between 0.70 and 0.99.

Table (4): Relationship Between Educational Level and Profit Efficiency (Illiterate) Under Fixed Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
155425	615614	460189	0.75	

Profit Efficiency Results for Wheat Farmers by Educational Level (Elementary)

Reviewing the estimated profit efficiency for wheat farmers based on their educational level (elementary) reveals an average efficiency of 0.69. This implies that, for wheat farmers to attain efficiency, they must increase their profits by 31% while either maintaining the current levels of prices and productivity or by adjusting them such that productivity increases by 31% at the same efficiency level. Comparison of the actual profits, which amount to 493,484 dinars per donum, with the estimated marginal profits of 706,033 dinars per donum indicates a loss in potential profits, amounting to 212,550 dinars per donum, due to inefficiency. Moreover, 22% of the farmers achieved a profit efficiency of less than 50%, 31% achieved an efficiency in the range of 0.51–0.69, and the remaining 65% achieved an efficiency between 0.70 and 0.99.

Table (5): Relationship Between Educational Level and Profit Efficiency (Elementary) Under Fixed Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
212550	706033	493484	0.69	

Profit Efficiency Results for Wheat Farmers by Educational Level (Intermediate)

Reviewing the estimated profit efficiency for wheat farmers according to their educational level (intermediate) reveals an average efficiency of 0.72. This implies that for these farmers to operate efficiently, their profits must be increased by 28% while maintaining the current levels of prices and productivity—or, alternatively, prices and productivity may be adjusted so that productivity is increased by 28% at this level of efficiency. Comparing the actual profits of 531,203 dinars per donum with the estimated marginal profits of 697,796 dinars per donum shows a profit loss due to inefficiency of 166,593 dinars per donum. Furthermore, 13% of the farmers achieved profit efficiency levels below 50%, 10% attained efficiency in the range of 0.51–0.69, and the remaining 77% obtained efficiency levels between 0.70 and 0.99.

Table (6): Relationship Between Educational Level and Profit Efficiency (Intermediate) Under Fixed Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
166593	697796	531203	0.72	

Profit Efficiency Results for Wheat Farmers by Educational Level (Preparatory)

Reviewing the estimated profit efficiency for wheat farmers by educational level (preparatory) reveals an average efficiency of 0.71. This indicates that for these farmers to operate efficiently, their profits must increase by 29% while maintaining current price and productivity levels—or the price and productivity parameters should be adjusted so as to achieve a 29% increase in productivity at this level of efficiency. Comparing the actual profits, which amount to 501,971 dinars per donum, with the estimated marginal profits of 678,585 dinars per donum shows a loss in profits due to inefficiency of 176,614 dinars per donum. Moreover, 14% of the farmers achieved a profit efficiency of less than 50%, 27% attained an efficiency ranging from 0.51 to 0.69, while the remaining 59% achieved efficiency levels between 0.70 and 0.99.

Table (7): Relationship Between Educational Level and Profit Efficiency (Preparatory) Under Fixed Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
176614	678585	501971	0.71	

Profit Efficiency Results for Wheat Farmers by Educational Level (Bachelor's)

Reviewing the estimated profit efficiency for wheat farmers according to their educational level (Bachelor's) indicates an average efficiency of 0.72. This means that for these farmers to operate efficiently, their profits must increase by 28% while maintaining the current levels of prices and productivity—or alternatively, the prices and productivity settings could be adjusted to achieve a 28% increase in production at this efficiency level. By comparing the

actual profits of 605,222 dinars per donum with the estimated marginal profits of 846,898 dinars per donum, it is evident that a loss of 241,676 dinars per donum occurs due to inefficiency. Furthermore, 15% of the farmers achieved a profit efficiency of less than 50%, 22% reached an efficiency in the range of 0.51–0.69, while the remaining 63% of wheat farmers achieved efficiency levels between 0.70 and 0.99.

Table (8): Relationship Between Educational Level and Profit Efficiency (Bachelor's) Under Fixed Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
241676	846898	605222	0.72	

3- Profit Efficiency Results for Wheat Farmers by Supplemental Irrigation Experience

Reviewing the estimated profit efficiency for wheat farmers with supplemental irrigation experience of 1–10 years reveals an average efficiency of 0.73. This indicates that, for these farmers to operate efficiently, profits must increase by 27% while maintaining current levels of prices and productivity—or alternatively, the price–productivity settings must be adjusted so that a 27% increase in productivity is achieved at this level of efficiency. By comparing the actual profits of 533,733 dinars per donum with the estimated marginal profits of 714,958 dinars per donum, it is apparent that a profit shortfall of 181,225 dinars per donum occurs due to inefficiency. Moreover, 15% of the farmers achieved profit efficiencies of less than 50%, 11% attained an efficiency within the range of 0.51–0.69, while the remaining 74% achieved efficiency levels between 0.70 and 0.99.

Table (9): Relationship Between Supplemental Irrigation Experience and Profit Efficiency (1–10) Under Fixed Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
181225	714958	533733	0.73	

Profit Efficiency Results for Wheat Farmers by Supplemental Irrigation Experience (11–20 Years)

Reviewing the estimated profit efficiency for wheat farmers with supplemental irrigation experience spanning 11–20 years reveals an average efficiency of 0.67. This means that for these farmers to operate efficiently, their profits must increase by 33% while maintaining current price and productivity levels—or, alternatively, the price–productivity parameters should be adjusted so that productivity increases by 33% at this level of efficiency. By comparing the actual profits of 441,179 dinars per donum with the estimated marginal profits of 649,095 dinars per donum, it is evident that a profit shortfall of 207,915 dinars per donum exists due to inefficiency. Moreover, 19% of the farmers achieved a profit efficiency of less than 50%, 22% attained an efficiency within the range of 0.51–0.69, while the remaining 59% recorded efficiency levels between 0.70 and 0.99.

Table (10): Relationship Between Supplemental Irrigation Experience and Profit Efficiency (11–20 Years) Under Fixed Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
207915	649095	441179	0.67	

Profit Efficiency Results for Wheat Farmers by Supplemental Irrigation Experience (21 Years or More)

Reviewing the estimated profit efficiency for wheat farmers with supplemental irrigation experience of 21 years or more reveals an average efficiency of 0.72. This indicates that, in order for these farmers to operate efficiently, their profits must increase by 28% while maintaining current levels of prices and productivity—or, alternatively, by adjusting prices and productivity to achieve a 28% increase in output at this level of efficiency. By comparing the actual profits of 479,045 dinars per donum with the estimated marginal profits of 636,282 dinars per donum, it is evident that a profit shortfall of 157,237 dinars per donum exists due to inefficiency. Moreover, 11% of the farmers achieved profit efficiencies of less than 50%, 33% obtained efficiency levels in the range of 0.51–0.69, while the remaining 56% achieved efficiency levels between 0.70 and 0.99.

Table (11): Relationship Between Supplemental Irrigation Experience and Profit Efficiency (21 Years or More) Under Fixed Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
157237	636282	479045	0.72	

4- Profit Efficiency Results for Wheat Farmers by Farmer's Age

Reviewing the estimated profit efficiency for wheat farmers by farmer's age (1–45 years) reveals an average efficiency of 0.75. This indicates that for wheat farmers to be efficient, their profits must increase by 25% while maintaining current levels of prices and productivity—or alternatively, adjustments in prices and productivity must be made to achieve a 25% increase in output at that efficiency level. Comparing the actual profits of 533,050 dinars per donum with the estimated marginal profits of 703,905 dinars per donum shows a profit shortfall of 170,855 dinars per donum due to inefficiency. Moreover, 11% of the farmers achieved profit efficiencies below 50%, 13% attained efficiencies in the range of 0.51–0.69, while the remaining 76% achieved efficiencies between 0.70 and 0.99.

Table (12): Relationship Between Farmer's Age and Profit Efficiency (1–45) Under Fixed Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
170855	703905	533050	0.75	

Profit Efficiency Results for Wheat Farmers by Farmer's Age (45 Years or More)

Reviewing the estimated profit efficiency for wheat farmers with a farmer's age of 45 years or more reveals an average efficiency of 0.69. This indicates that for these farmers to operate efficiently, their profits must increase by 31% while maintaining the current levels of prices and productivity—or, alternatively, the price–productivity settings must be adjusted so that there is a 31% increase in output at this level of efficiency. Comparing the actual profits of 486,649 dinars per donum with the estimated marginal profits of 689,534 dinars per donum shows a profit shortfall of 202,885 dinars per donum due to inefficiency. Moreover, 18% of the farmers achieved a profit efficiency of less than 50%, 17% attained an efficiency in the range of 0.51–0.69, while the remaining 65% achieved efficiency levels between 0.70 and 0.99.

Table (13): Relationship Between Farmer's Age and Profit Efficiency (45 Years or More) Under Fixed Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
202885	689534	486649	0.69	

5- Profit Efficiency Results for Wheat Farmers by Cultivation Experience

Reviewing the estimated profit efficiency for wheat farmers with crop cultivation experience of 1–6 years reveals an average efficiency of 0.78. This indicates that for these farmers to be efficient, they must either increase their profits by 22% while maintaining the current price and productivity levels, or adjust prices and productivity so that a 22% increase in output is achieved at this efficiency level. Comparing the actual profits of 501,899 dinars per donum with the estimated marginal profits of 647,590 dinars per donum, it becomes evident that a profit shortfall of 145,690 dinars per donum exists due to inefficiency. Moreover, 6% of the farmers achieved a profit efficiency below 50%, 11% recorded an efficiency in the range of 0.51–0.69, while the remaining 83% attained efficiency levels between 0.70 and 0.99.

Table (14): Relationship Between Cultivation Experience and Profit Efficiency (1–6 Years) Under Fixed Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
145690	647590	501899	0.78	

Profit Efficiency Results for Wheat Farmers by Cultivation Experience

Reviewing the estimated profit efficiency for wheat farmers with crop cultivation experience of 7–17 years reveals an average efficiency of 0.71. This indicates that for these farmers to operate efficiently, their profits must increase by 29% while maintaining current levels of prices and productivity—or alternatively, the pricing and productivity parameters must be adjusted to achieve a 29% increase in output at this efficiency level. Comparing the actual profits, which amount to 485,217 dinars per donum, with the estimated marginal profits of

669,711 dinars per donum shows a profit shortfall due to inefficiency of 184,494 dinars per donum. Moreover, 17% of the farmers achieved a profit efficiency of less than 50%, 13% recorded an efficiency in the range of 0.51–0.69, and the remaining 70% achieved efficiency levels between 0.70 and 0.99.

Table (15): Relationship Between Cultivation Experience and Profit Efficiency (7–17 Years) Under Fixed Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
184494	669711	485217	0.71	

Profit Efficiency Results for Wheat Farmers by Cultivation Experience (18 Years or More)

Reviewing the estimated profit efficiency for wheat farmers with crop cultivation experience of 18 years or more reveals an average efficiency of 0.71. This indicates that for these farmers to operate efficiently, their profits must be increased by 29% while maintaining current levels of prices and productivity—or alternatively, a reduction in prices accompanied by an increase in productivity by 29% is required at this efficiency level. By comparing the actual profits of 534,537 dinars per donum with the estimated marginal profits of 734,504 dinars per donum, it becomes evident that there is a profit shortfall due to inefficiency amounting to 199,967 dinars per donum. Moreover, 15% of the farmers achieved profit efficiencies of less than 50%, 18% recorded efficiencies between 0.51 and 0.69, while the remaining 67% attained efficiency levels between 0.70 and 0.99.

Table (16): Relationship Between Cultivation Experience and Profit Efficiency (18 Years or More) Under Fixed Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
199967	734504	534537	0.71	

Table (17): Results of the Superior Logarithmic Profit Function (TL) and the Inefficiency Model for Pivot Irrigation

Parameter	coefficient	standard-error	t-ratio
beta 0	3.557	0.996	3.569 ***
beta 1	0.756	0.061	12.373 ***
beta 2	0.596	0.118	5.041***
beta 3	-0.163	0.037	-4.399 ***
beta 4	0.140	0.0427	3.285 ***
beta 5	-0.095	0.0427	-2.227 **

beta 6	0.230	0.0511	4.5026 ***
beta 7	-0.0914	0.0483	-1.890 **
Beta 8	-0.0739	0.0486	-1.521 *
delta 0	-8.188	2.6342	-3.108 ***
delta 1	-0.1704	0.1082	-1.5740 *
delta 2	-1.988	0.589	-3.371***
delta 3	-0.0781	0.0431	-1.8098 **
delta 4	0.1318	0.0406	3.2451 ***
delta 5	0.1064	0.0394	2.6980 ***
sigma-squared	.030	0.7826	3.8678 ***
gamma	0.99	0.00153	650.257 ***
log likelihood function	-67.686		

Source: Researcher's own work using Frontier 4.1

*Significant at the 10% level, ** Significant at the 5% level ,*** Significant at the 1% level

A. The sigma squared (2σ) value is estimated at 0.30 and is statistically significant at the 0.05 level. This significance confirms that the assumed distribution for the composite error term is both appropriate and accurate (Bhar et al., 2020:175).

B. The Gamma (Γ) value, recorded at 0.99 and significant at the 0.01 level, indicates that nearly all of the deviations from the profit frontier—amounting to 99%—are due to profit inefficiency rather than random error. In other words, 99% of the production variability is explained by inefficiency attributed to the technological variables analyzed in the study (Lee & Park, 2019:45–60).

C. The one-sided log-likelihood ratio (LR) test produced a value of 275.232, which is statistically significant at both the 0.01 and 0.05 levels. This value far exceeds the chi-square critical thresholds of 18.475 and 14.067, respectively. Consequently, this finding supports the alternative hypothesis—that there is a significant relationship between the technological variables implemented at the farm (namely, family size, educational level, supplementary irrigation experience, farmer's age, and crop cultivation experience) and profit frontier inefficiency—leading to the rejection of the null hypothesis.

A. Profit Function Parameters:

The findings indicate that the estimated coefficients for output price, land price, human labor hours, and water usage are both statistically significant and positively associated with profit levels. Specifically, a 1% increase in each of these variables corresponds to an estimated rise in profits of approximately 0.756%, 0.596%, 0.140%, and 0.230%, respectively. From an economic standpoint, the positive effect of output price highlights the direct relationship

between increased production and enhanced profitability. Similarly, rising land prices often signal government interventions—such as support for staple crops like wheat—that incentivize farmers to expand cultivation despite escalating costs. In terms of labor, the seasonal nature of wheat farming generates concentrated periods of labor demand; during these peak times, limited rural labor supply tends to elevate wage rates. Climatic stressors, particularly reduced rainfall, further compel farmers to intensify irrigation use, leading to increased water expenditures. Conversely, the coefficients for pesticide, mechanization, seed, and fertilizer prices are statistically significant but negative. This suggests that a 1% increase in the cost of these inputs is associated with profit declines of roughly 0.163%, 0.095%, 0.0914%, and 0.0739%, respectively. These findings underscore the financial sensitivity of farm profitability to input cost fluctuations, particularly in the context of intensive input use.

B- Parameter Estimates for the Profit Inefficiency Model: Family Size (D1): A statistically significant and negative coefficient is observed for family size, suggesting an inverse relationship with profit inefficiency. Larger family sizes are associated with decreased profit inefficiency.

1. **Level of Education** (D2): Similarly, the coefficient for educational level is statistically significant and negative, indicating that higher educational attainment contributes to lower profit inefficiency.

2. **Experience in Supplementary Irrigation** (D3): The analysis demonstrates a statistically significant and negative coefficient for supplementary irrigation experience. This suggests that greater familiarity with supplementary irrigation techniques leads to a decrease in profit inefficiency.

3. **Age of the Farmer** (D4): In contrast, a positive coefficient that is statistically significant has been identified for the age of the farmer. This indicates a positive correlation between the age of a farmer and profit inefficiency, suggesting that profit inefficiency is likely to rise with increasing age..

4. Crop Cultivation Experience (D5): Ultimately, the coefficient pertaining to experience in crop cultivation is both statistically significant and positive, suggesting that increased experience in this domain correlates with a rise in profit inefficiency. (Wang & Chen, 2022:195).

Profit Efficiency Results and Analysis for Wheat Farmers Under Center Pivot Irrigation

1- Profit Efficiency Results by Household Size

For Household Sizes 1–6:

Reviewing the estimated profit efficiency for wheat farmers with household sizes of 1–6 shows an average efficiency of 0.75. This implies that to achieve efficiency, these farmers must either increase their profits by 25% while maintaining current price and productivity levels, or adjust the pricing–productivity mix so that a 25% increase in output is reached at that level of efficiency. A comparison of the actual profits, which are 491,837 dinars per donum, with the estimated marginal profits of 643,406 dinars per donum reveals a loss of

151,569 dinars per donum due to inefficiency. In this group, 10% of the farmers attained profit efficiency of less than 50%, 16% achieved an efficiency in the range of 0.51–0.69, and the remaining 74% recorded efficiencies between 0.70 and 0.99.

For Household Sizes 7–20:

For wheat farmers belonging to households with 7–20 members, the estimated average profit efficiency is 0.71. This indicates that for these farmers to operate efficiently, profits should be increased by 29%—either by maintaining the current levels of prices and productivity or by adjusting both parameters to secure a 29% increase in productivity at this efficiency level. Comparing the actual profits of 528,865 dinars per donum with the estimated marginal profits of 694,952 dinars per donum, one can observe that inefficiency accounts for a loss of 166,087 dinars per donum. In this category, 15% of the farmers obtained profit efficiencies below 50%, 18% reached an efficiency between 0.51 and 0.69, while the remaining 67% achieved efficiencies within the range of 0.70–0.99.

Table (18): Relationship Between Household Size (1–6) and Profit Efficiency Under Center Pivot Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
151569	643406	491837	0.75	

Table (19): Relationship Between Household Size (7–20) and Profit Efficiency Under Center Pivot Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
166087	694952	528865	0.71	

2- Profit Efficiency Results for Wheat Farmers by Educational Level (Illiterate)

Reviewing the estimated profit efficiency for wheat farmers by educational level (illiterate) reveals an average efficiency of 0.64. This means that for these farmers to operate efficiently, their profits must be increased by 36%—either by maintaining current prices and productivity levels or by modifying both prices and productivity such that a 36% increase in output is achieved at this level of efficiency. Comparing the actual profits of 455,732 dinars per donum with the estimated marginal profits of 639,872 dinars per donum shows a profit shortfall due to inefficiency of 184,140 dinars per donum. Moreover, 23% of the farmers achieved profit efficiencies below 50%, 27% recorded efficiencies in the range of 0.51–0.69, and the remaining 50% attained efficiencies between 0.70 and 0.99.

Table (20): Relationship Between Educational Level (Illiterate) and Profit Efficiency Under Center-Pivot Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
184140	639872	455732	0.64	

Profit Efficiency Results for Wheat Farmers by Educational Level (Elementary)

Reviewing the estimated profit efficiency for wheat farmers by educational level (elementary) reveals an average efficiency of 0.75. This indicates that for these farmers to operate efficiently, their profits must increase by 25% while maintaining current levels of prices and productivity—or, alternatively, prices and productivity could be adjusted to achieve a 25% increase in output at this level of efficiency. Comparing the actual profits of 567,597 dinars per donum with the estimated marginal profits of 732,066 dinars per donum shows a profit shortfall of 164,469 dinars per donum due to inefficiency. Furthermore, 9% of the farmers achieved a profit efficiency of less than 50%, 31% recorded an efficiency between 0.51 and 0.69, while the remaining 78% attained efficiency levels between 0.70 and 0.99.

Table (21): Relationship Between Educational Level (Elementary) and Profit Efficiency Under Center-Pivot Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
164469	732066	567597	0.75	

Profit Efficiency Results for Wheat Farmers by Educational Level (Intermediate)

Reviewing the estimated profit efficiency for wheat farmers by educational level (intermediate) reveals an average efficiency of 0.73. This means that for these farmers to be efficient, they must either increase their profits by 27% while maintaining current levels of prices and productivity—or adjust the price–productivity setup such that output increases by 27% at this efficiency level. Comparing the actual profits of 483,206 dinars per donum with the estimated marginal profits of 641,204 dinars per donum shows a profit shortfall of 157,999 dinars per donum due to inefficiency. Moreover, 14% of the farmers recorded profit efficiencies below 50%, 14% attained efficiencies in the range of 0.51–0.69, while the remaining 72% achieved efficiencies between 0.70 and 0.99.

Table (22): Relationship Between Educational Level (Intermediate) and Profit Efficiency Under Center-Pivot Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
157999	641204	483206	0.73	

Profit Efficiency Results for Wheat Farmers by Educational Level (Preparatory)

Reviewing the estimated profit efficiency for wheat farmers by educational level (preparatory) reveals an average efficiency of 0.78. This implies that, for these farmers to be efficient, their profits must increase by 22% while maintaining current levels of prices and productivity—or, alternatively, the pricing–productivity configuration must be adjusted so that a 22% increase in output is achieved at this level of efficiency. By comparing the actual profits of 613,633 dinars per donum with the estimated marginal profits of 770,649 dinars per

donum, it is evident that a profit shortfall of 157,016 dinars per donum arises due to inefficiency. Moreover, 11% of the farmers achieved profit efficiencies below 50%, another 11% recorded efficiencies in the range of 0.51–0.69, and the remaining 78% attained efficiencies between 0.70 and 0.99.

Table (23): Relationship Between Educational Level (Preparatory) and Profit Efficiency Under Center-Pivot Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
157016	770649	613633	0.78	

Profit Efficiency Results for Wheat Farmers by Educational Level (Bachelor's)

Reviewing the estimated profit efficiency for wheat farmers with a Bachelor's degree reveals an average efficiency of 0.81. This implies that for these farmers to operate efficiently, their profits must increase by 19% while maintaining current levels of prices and productivity—or, alternatively, adjustments in prices and productivity must be made to yield a 19% increase in output at this efficiency level. Comparing the actual profits of 481,578 dinars per donum with the estimated marginal profits of 578,226 dinars per donum indicates a profit shortfall of 96,648 dinars per donum due to inefficiency. Additionally, while none of the farmers attained a profit efficiency below 50%, 17% achieved an efficiency in the range of 0.51–0.69, and the remaining 83% recorded efficiencies between 0.70 and 0.99.

Table (24): Relationship Between Educational Level (Bachelor's) and Profit Efficiency Under Center-Pivot Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
96648	578226	481578	0.81	

3- Profit Efficiency Results for Wheat Farmers by Supplemental Irrigation Experience

Reviewing the estimated profit efficiency for wheat farmers with supplemental irrigation experience of 1–10 years reveals an average efficiency of 0.72. This indicates that for these farmers to be efficient, their profits must increase by 28% while maintaining current price and productivity levels—or, alternatively, the pricing–productivity setup must be adjusted to achieve a 28% increase in output at this efficiency level. By comparing the actual profits of 502,608 dinars per donum with the estimated marginal profits of 661,150 dinars per donum, it becomes evident that there is a profit shortfall of 158,542 dinars per donum due to inefficiency. Furthermore, 15% of the farmers achieved profit efficiencies below 50%, 16% recorded efficiencies in the range of 0.51–0.69, and the remaining 69% attained efficiencies between 0.70 and 0.99.

Table (25): Relationship Between Supplemental Irrigation Experience and Profit Efficiency (1–10) Under Center-Pivot Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
158542	661150	502608	0.72	

Profit Efficiency Results for Wheat Farmers by Supplemental Irrigation Experience (11–20 Years)

Reviewing the estimated profit efficiency for wheat farmers with supplemental irrigation experience of 11–20 years reveals an average efficiency of 0.73. This indicates that for these farmers to operate efficiently, they must increase their profits by 27% while maintaining current levels of prices and productivity—or, alternatively, adjust prices and productivity to achieve a 27% increase in output at this level of efficiency. By comparing the actual profits of 569,332 dinars per donum with the estimated marginal profits of 756,057 dinars per donum, it is evident that a profit shortfall of 186,725 dinars per donum arises due to inefficiency. Moreover, 8% of the farmers achieved a profit efficiency of less than 50%, 23% attained an efficiency in the range of 0.51–0.69, while the remaining 69% achieved profit efficiencies between 0.70 and 0.99.

Table (26): Relationship Between Supplemental Irrigation Experience and Profit Efficiency (11–20 Years) Under Center-Pivot Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
186725	756057	569332	0.73	

Profit Efficiency Results for Wheat Farmers by Supplemental Irrigation Experience (21 Years or More)

Reviewing the estimated profit efficiency for wheat farmers with supplemental irrigation experience of 21 years or more reveals an average efficiency of 0.75. This indicates that for these farmers to be efficient, their profits must increase by 25% while maintaining current price and productivity levels—or alternatively, adjustments in prices and productivity should be made to achieve a 25% increase in output at this level of efficiency. By comparing the actual profits of 534,804 dinars per donum with the estimated marginal profits of 641,266 dinars per donum, it is evident that a profit shortfall of 106,462 dinars per donum exists due to inefficiency. Moreover, 11% of the farmers attained profit efficiencies below 50%, another 11% achieved efficiencies in the range of 0.51–0.69, while the remaining 78% recorded profit efficiencies between 0.70 and 0.99.

Table (27): Relationship Between Supplemental Irrigation Experience (21 Years or More) and Profit Efficiency Under Center-Pivot Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
106462	641266	534804	0.75	

4- Profit Efficiency Results for Wheat Farmers by Farmer's Age

Reviewing the estimated profit efficiency for wheat farmers with a farmer's age between 1 and 45 years reveals an average efficiency of 0.77. This implies that for these farmers to operate efficiently, their profits must increase by 23% while maintaining current levels of prices and productivity—or, alternatively, by adjusting both prices and productivity such that a 23% increase in output is achieved at this level of efficiency. By comparing the actual profits of 589,551 dinars per donum with the estimated marginal profits of 740,259 dinars per donum, it is evident that a profit shortfall of 150,708 dinars per donum arises due to inefficiency. Additionally, 7% of the farmers achieved profit efficiencies below 50%, 14% recorded efficiencies in the range of 0.51–0.69, while the remaining 79% attained efficiencies between 0.70 and 0.99.

Table (28): Relationship Between Farmer's Age (1–45) and Profit Efficiency Under Center-Pivot Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
150708	740259	589551	0.77	

Profit Efficiency Results for Wheat Farmers by Farmer's Age (45 Years or More)

Reviewing the estimated profit efficiency for wheat farmers with a farmer's age of 45 years or more reveals an average efficiency of 0.68. This means that for these farmers to operate efficiently, their profits must be increased by 32% while maintaining current levels of prices and productivity—or alternatively, prices and productivity must be adjusted to achieve a 32% increase in output at this efficiency level. By comparing the actual profits of 454,088 dinars per donum with the estimated marginal profits of 624,544 dinars per donum, it is evident that a profit shortfall of 170,456 dinars per donum arises due to inefficiency. Moreover, 19% of the farmers achieved profit efficiencies below 50%, 18% attained efficiencies in the range of 0.51–0.69, while the remaining 63% recorded profit efficiencies between 0.70 and 0.99.

Table (29): Relationship Between Farmer's Age (45 Years or More) and Profit Efficiency Under Center-Pivot Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
170456	624544	454088	0.68	

5- Profit Efficiency Results for Wheat Farmers by Cultivation Experience

Reviewing the estimated profit efficiency for wheat farmers with crop cultivation experience of 1–6 years reveals an average efficiency of 0.80. This indicates that for these farmers to be efficient, their profits must increase by 20% while either maintaining current levels of prices and productivity or by adjusting these parameters so that a 20% increase in output is achieved at this efficiency level. By comparing the actual profits of 651,104 dinars per donum with the estimated marginal profits of 810,801 dinars per donum, it is evident that a profit deficit of

159,698 dinars per donum arises due to inefficiency. Moreover, 3% of the farmers achieved profit efficiencies below 50%, 9% recorded efficiencies in the range of 0.51–0.69, while the remaining 88% attained efficiencies between 0.70 and 0.99.

Table (30): Relationship Between Cultivation Experience (1–6 Years) and Profit Efficiency Under Center-Pivot Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
159698	810801	651104	0.80	

Profit Efficiency Results for Wheat Farmers by Cultivation Experience (7–17 Years)

Reviewing the estimated profit efficiency for wheat farmers with crop cultivation experience of 7–17 years reveals an average efficiency of 0.70. This indicates that for these farmers to operate efficiently, their profits must increase by 30% while maintaining the current levels of prices and productivity—or, alternatively, the pricing and productivity parameters must be adjusted so that a 30% increase in output is achieved at this efficiency level. By comparing the actual profits of 489,345 dinars per donum with the estimated marginal profits of 660,120 dinars per donum, it is evident that there is a profit gap of 170,775 dinars per donum due to inefficiency. Additionally, 15% of the farmers achieved profit efficiencies below 50%, 20% recorded efficiencies in the range of 0.51–0.69, and the remaining 65% attained efficiencies between 0.70 and 0.99.

Table (31): Relationship Between Cultivation Experience (7–17 Years) and Profit Efficiency Under Center-Pivot Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
170775	660120	489345	0.70	

Profit Efficiency Results for Wheat Farmers by Cultivation Experience (18 Years or More)

Reviewing the estimated profit efficiency for wheat farmers with crop cultivation experience of 18 years or more reveals an average efficiency of 0.72. This indicates that for these farmers to operate efficiently, their profits must increase by 28% while maintaining current levels of prices and productivity—or, alternatively, by adjusting prices and productivity to obtain a 28% increase in output at this level of efficiency. By comparing the actual profits of 485,103 dinars per donum with the estimated marginal profits of 631,877 dinars per donum, it is evident that a profit shortfall of 146,774 dinars per donum arises due to inefficiency. Moreover, 17% of the farmers achieved profit efficiencies of less than 50%, 14% reached efficiencies in the range of 0.51–0.69, while the remaining 69% attained efficiencies between 0.70 and 0.99.

Table (32): Relationship Between Cultivation Experience (18 Years or More) and Profit Efficiency Under Center-Pivot Irrigation

Profit Loss	Marginal Profit	Actual Profit	Efficiency	Average
146774	631877	485103	0.72	

CONCLUSIONS

1. Factors Influencing Profitability: Elements that affect production, including output prices, labor hours, land rentals, and water usage, demonstrate a positive relationship with profitability. In contrast, rising costs associated with seeds and pesticides typically apply downward pressure on profit margins.

2. Influences of Inefficiency: The findings of the study reveal that factors such as larger family sizes and enhanced agricultural experience play a role in diminishing inefficiency. Conversely, increased age among farmers, elevated levels of education, and greater experience with supplementary irrigation correlate with heightened inefficiency.

3. Strategic Recommendations: To attain optimal profitability, it is essential to combine contemporary technologies with efficient management strategies. This integration calls for the formulation of agricultural policies tailored to local circumstances, along with the provision of necessary training and support for farmers. (Johnson & Davis, 2020:119–130).

RECOMMENDATIONS

1. Resource Optimization: It is advisable to conduct a strategic reevaluation of target production volumes to reduce excessive dependence on costly inputs. By implementing intensive farming practices and reallocating agricultural land, land use efficiency can be improved, thereby alleviating financial burdens. Additionally, enhancing labor management through the optimization of work schedules and the integration of suitable technologies can decrease reliance on manual labor. The crucial adoption of contemporary irrigation methods, such as drip irrigation, is essential for ensuring effective water utilization and minimizing overall consumption.
2. Policy Interventions: It is essential to establish supportive policies that grant farmers access to credit facilities and tailored assistance programs. At the same time, there is a necessity for regulatory measures aimed at regulating input prices that adversely affect profitability. Such initiatives will safeguard farmers from the harmful consequences of rising input costs while ensuring the quality of production is upheld.
3. Research and Development: It is crucial to advocate for field studies and applied research aimed at the advancement of innovative technologies and the reorganization of agricultural processes to optimize resource utilization efficiency. In a context marked by persistently rising input expenses, ongoing research in this domain has the potential to produce transformative solutions that greatly enhance profitability [Khan et al., 2018:115–132].

Source of the Tables:

Calculated based on the results of the random marginal profit function.

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