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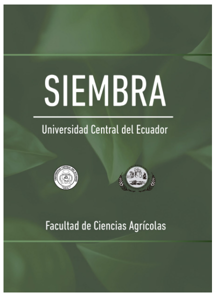

Eficiencia económica de la producción de trigo a pequeña escala en el estado de Jigawa, Nigeria

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Abstract

Africa's most populous country has failed to grow more food for its fast-rising population. With 420,000 metric tons of wheat produced in Nigeria in 2020, the country is still far from bridging its 4.6 million metric tons annual wheat gap. Increasing wheat production is a challenge for the nation to fulfill the food requirements of its growing population. So far literature has shown a rise in research on wheat in different parts of Nigeria, with a paucity of information on the economic efficiency of wheat production in the study area, and the country in general. To bridge these knowledge and empirical gaps, this research investigates the economic efficiency of wheat production in Jigawa State of Nigeria using information gathered from a survey elicited by a well-structured questionnaire coupled with an interview schedule from 341 active wheat farmers selected through a multi-stage sampling technique. Both descriptive and inferential statistics were used to analyze the data collected. Empirically, despite the wheat enterprise being profitable in the study area, farmers didn't achieve the targeted goals of output maximization, cost minimization, and profit maximization as evident respectively by the technical, cost, and economic efficiency indexes. However, these goals were challenged by induced human risks *viz.* gender discrimination that affects women's access to productive resources, poor labor productivity due to diminishing marginal returns associated with old age, capital consumption triggered by increased income, poor prioritization of wheat enterprise as a business, and vulnerable household size. Furthermore, the identified constraints mediating the links that affected the economic efficiency of wheat farmers were price/marketing, technological, managerial, and infrastructural risks. Therefore, for long-run sustainable wheat production, the responsibility lies on policymakers to concentrate more on marketing and technological risks challenging wheat production in the study area as empirically established by this research.

Keywords: efficiency, economic, wheat, farmers, Nigeria

Resumen

El país más poblado de África no ha logrado producir más alimentos para una población en rápido crecimiento. Nigeria produjo 420.000 toneladas métricas de trigo en 2020, estando aún lejos de cubrir su déficit anual de 4,6 millones de toneladas métricas de trigo. Por tanto, aumentar la producción de trigo es un reto para que el país satisfaga las necesidades alimentarias de su creciente población. En la literatura actual se evidencia un aumento de investigaciones sobre trigo en diferentes partes de Nigeria, pero existe una escasez de información sobre la eficiencia económica de la producción de trigo en la zona de estudio, y en el país en general. Para cubrir estas lagunas empíricas y de conocimiento, se analizó la eficiencia económica de la producción de trigo en el estado nigeriano de Jigawa. La información fue obtenida a través de una encuesta, con un cuestionario estructurado, y un programa de entrevistas, a 341 agricultores de trigo activos seleccionados mediante una técnica de muestreo multietápico. Los datos recogidos fueron analizados mediante estadística descriptiva e inferencial. Los resultados empíricos muestran que a pesar de que la producción de trigo es rentable en la zona estudiada, los agricultores no alcanzaron los objetivos fijados de maximización de la producción, minimización de costos y maximización de beneficios, como lo demuestran los índices obtenidos de eficiencia técnica, de costos y económica, respectivamente. Sin embargo, estos objetivos se vieron dificultados por los riesgos humanos inducidos, a saber, la discriminación de género que afecta al acceso de las mujeres a los recursos productivos, la escasa productividad laboral debida a la disminución de los rendimientos marginales asociada a la vejez, el consumo de capital provocado por el aumento de los ingresos, la escasa priorización de la empresa triguera como negocio y, el tamaño de los hogares vulnerables. Además, las limitantes identificadas que intervienen en los vínculos que afectan a la eficiencia económica de los cultivadores de trigo fueron los riesgos de comercialización del producto, tecnológicos, de gestión y de infraestructura. Por tanto, para que la producción de trigo sea sostenible a largo plazo, los responsables políticos tienen la responsabilidad de concentrarse más en los riesgos tecnológicos y de comercialización que dificultan la producción de trigo en la zona estudiada, tal y como establece empíricamente esta investigación.

Palabras clave: eficiencia, economía, trigo, agricultores, Nigeria

1. Introduction

The recent Russian invasion of Ukraine has had an impact on the world's wheat supply chain, driving wheat prices to all-time highs (Sadiq et al., 2022a). According to the National Bureau of Statistics [NBS] data on foreign commerce, Nigeria imported durum wheat worth ₦1.29 trillion in 2021[1] (Alabi, 2022). The figures showed a rise of 71.1 % over the ₦756.92 billion recorded in 2020 and a more than threefold increase over the ₦401.31 billion recorded in 2019. The item accounts for 6.2 % of Nigeria's overall import expenditure, making it the second-highest contributor and the most expensive food import (Alabi, 2022). Moreover, five million tons of wheat are currently needed by the nation, but just 2.06 % of that amount is produced (Startup Tips Daily Media, 2023). Ekkot (2021) claims that Nigeria's wheat output has been so reduced that, for the last ten years the nation only succeeded in producing just less than 2 % of the total amount of wheat it consumed. According to data from the United States Department of Agriculture, as wheat consumption worldwide increased between 2010 and 2020, Nigeria failed to increase wheat production and instead dramatically increased wheat imports to make up for the shortfall in supply (Ekkot, 2021). Nigerian wheat production, which is estimated at 2.5 million metric tons, is hardly impressive for a nation that prides itself on being Africa's behemoth (Yammama, 2023). If Nigeria is unable to increase its rate of growth in wheat output, the situation could get worse.

The rapidly expanding population, increased urbanization, rising wages, and a shift in food preferences away from traditional cereals toward wheat and wheat products are the main causes of the rising domestic demand for wheat (Hailekiros et al., 2018; Koondhar et al., 2018; Tleubayev et al, 2022). Although there is potential for the country to increase wheat production, the industry faces several obstacles, including high input costs (seeds, biocides, and fertilizers), lack of farm equipment, expensive fuel, unstable producer prices, and the division of large farms into smaller units. Even though wheat breeders have worked extremely hard over the past three decades to create innovative and high-yielding varieties, Nigeria's wheat production has consistently fallen short of demand, leaving imports as the only option to make up the difference.

The foundation for achieving national food security and poverty alleviation goals is efficient production, especially in areas of the nation with the greatest potential for producing major food crops (Asfaw et al., 2019). However, inefficient agricultural production and disparities in producer efficiency deter farmers from increasing output (Asfaw et al., 2019; Chen et al., 2022; Dessale, 2019). When there is inefficiency, attempts to introduce new knowledge may not have the desired effect because the available knowledge is not being used

[1] $USD 1 = ₦ 448 (₦ means Nigerian Naira currency)

effectively. Inefficiency prevents benefits from emerging with enhanced inputs, which could increase gains from the utilization of existing resources. By allowing farmers to get the most output from a given quantity of inputs with the technology that is now available at their disposal, a rise in efficiency will thus boost productivity. Furthermore, if the goal is to boost agricultural productivity and farm household income, removing current inefficiencies among farmers may be more cost-effective than implementing new technologies (Dessale, 2019). Gains in agricultural productivity through increased efficiency are becoming increasingly significant in our society.

The study area's smallholder farmers are underprivileged and have small, unprofitable holdings, large families, and low land productivity, which left them unable to properly meet their households' food needs. Smallholder farming practices based on cereals have also continued to be conventional and non-commercial. As a result, the system cannot meet the demands of an ever-growing population for food and energy. To maximize outputs, farmers must either adopt current technologies or use resources efficiently due to the pressure of an ever-increasing population, environmental degradation, and the extension of marginal agricultural fields (Dessale, 2019). In the study area, small-scale farmers produce a great quantity of wheat, but they employ inputs and agronomic techniques very differently and produce wheat at a far lower rate than large-scale farmers. However, it is unknown how efficient each size category is and where inefficiencies originate. Because of this subsector's importance on farm incomes to the rural economy, regional integration is fostering higher levels of competition that require increased production and distribution efficiency. The subsector is crucial to the nation's strategies relating to achieving food self-sufficiency, creating rural employment, and reducing poverty, thus determining economic efficiency in wheat production is important.

With little knowledge regarding wheat production, numerous researchers have studied the efficiency of various arable crops in Nigeria. Nevertheless, farm efficiency investigation in wheat production in the nation is restricted to idiosyncratic factors and pseudo-profit estimates, which underestimate the advantages that producers could obtain from enhancements in overall performance. To the best of our knowledge based on reviews of published literatures, there is little or no information on the economic efficiency of wheat production in the study area in particular, and the country in general. It is against this background that this research attempted to determine the economic efficiency of small-scale wheat farmers in Jigawa State of Nigeria. The specific objectives were to estimate the costs and return of wheat production; determine the technical, costs, and economic efficiencies of wheat farms, and determine the constraints affecting wheat production and its consequence on the overall performance of wheat farmers.

2. Methods

2.1. Study area

Jigawa State is one of the 36 States in the country that shares common borders with Kano State and Katsina State to the West, Bauchi State to the East, and Yobe State to the Northeast. It has a shared international border with the Zinder Region of the Republic of Niger to the North, which presents a special possibility for cross-border trade activity (Jigawa State Government [JSG], 2017). It is in the country's Northwestern region between latitudes 11°N and 13°N and longitudes 8°E and 10.15°E. It is the eighth most populous state in terms of ethnic composition, with a predominance of Hausa and Fulani residents (JSG, 2017). According to Sadiq and Sani (2022), rainfall volume normally varies between 600 and 1000 millimeters during the rainy season, which runs from May to September. Its southern region presents heavier rainfall than the northern region (Sadiq and Sani, 2022). Jigawa State's land area is about 22,410 square kilometers, and the estimated population is 4,361,002 at 2006 (National Population Commission [NPC], 2006), with a current projection of 4,884,322 million people at a 3 % growth rate for the year 2021. Dunes of varied sizes that extend several kilometers in some areas add to its undulating geography. Hadejia, Kafin-Hausa, and Iggi Rivers are the primary rivers and other tributaries in the northeast feed large marshlands. The Hadejia and Kafin-Hausa Rivers traverse the state from west to east through the Hadejia-Nguru wetlands before emptying into the Lake Chad Basin. The state's economy is still heavily dependent on agriculture, and because of its semi-arid climate, workers frequently migrate to nearby states like Kano in search of seasonal work (JGS, 2021). One of the most valuable natural resources is its large tracts of lush arable land, to which nearly all tropical crops may adapt. A large portion of the Sudanese savannah vegetation zone consists of grazing areas that are ideal for raising livestock.

Using a multi-stage sampling technique, a total of 283 active wheat farmers were selected to participate in a survey following a series of steps. Firstly, given that wheat production cuts across all agricultural strata of the state, a saturated sampling frame of the stratified Jigawa State Agricultural and Rural Development Agency [JARDA] zones was taken: Zone 1 (Birnin-Kudu), Zone II (Hadejia), Zone III (Gumel) and Zone IV (Kazaure). Secondly, the major producing Local Government Areas [LGAs] in each zone were purposively selected: in Zones I, II, III, and IV the LAGs selected were Jahun, Ringim, Hadejia, and Kazaure respectively. Thirdly, from each of the selected LGAs, three (3) villages were randomly selected, giving a total of 12 villages to undertake the survey. Lastly, based on the sampling frame proposed by JARDA and the reconnaissance survey (Table 1), a Krejcie and Morgan formula (equation [1]) was used to generate a representative sample size for the study.

Table 1. Sampling scheme applied to select wheat farmers in the study area.

Zones	LGAs	Villages	Population	Sample size
Birnin Kudu Zone (Zone I)	Jahun	Harbo Tsohuwa	134	16
		Harbo Sabuwa	149	18
		Jama'a	137	17
Gumel Zone (Zone II)	Ringim	Ringim Town	130	16
		Gabarin	143	18
		Dabi	198	24
Hadejia Zone (Zone III)	Hadejia	Sunamu	178	22
		Mai Alkama	258	31
		Hago	184	23
Kazaure Zone (Zone IV)	Kazaure	Farin Daba	321	39
		Gada	230	28
		Tudun Wayo	250	31
Total 4	**4**	**12**	**2312**	**283**

$$\mathbf{X} = \frac{Z^2 \; x \; P(1-P)}{e^2} \quad \rightarrow \quad n_p = \frac{N(X)}{X+(N-1)} \quad [1]$$

Where, n_p = Sample size; N = Population size; e = Acceptable sampling error; X= Finite sample size; P = Proportion of the population

A total of 283 active wheat farmers were randomly selected. Using an easy cost-route approach, farm survey data for the 2022 wheat production season were gathered with the aid of a structured questionnaire coupled with an interview schedule. Objectives I, II, and III were achieved using the farm budgeting technique, stochastic frontier model, and factor analysis respectively.

2.2. Empirical model

2.2.1. Farm budgeting technique

The equations applied were:

$$NFI = TR - TC \quad [2]$$

$$GM = TR - TVC \quad [3]$$

$$ROI = \frac{GM}{TC} \quad [4]$$

$$ROCI = \frac{NFI}{TC} \quad [5]$$

Where, *NFI* = Net farm income/profit; *TR* = Total revenue; *TC* = Total cost (TVC+TFC); *TFC*= Total fixed cost; *ROI* = Return on investment; *TVC* = Total variable cost; *GM* = Gross margin; *ROCI* = Return on capital invested; *NFI* = Net Farm Income (GM – TFC).

2.2.2. Stochastic frontier model

Following Sadiq et al. (2021a, b, c), both he imposed Cobb-Douglas stochastic frontier production and cost functions are specified in equations [6] and [10].

$$Y_i = f(X_{ij}; \beta_i) + (V_i - U_i) \quad [6]$$

Where, Y_i = total output of the i[th] farmer; X_{ij} = vector of the actual j[th] input used by the i[th] farmer; β_i = parameter to be estimated; V_i = uncertainty which is beyond the control of the i[th] farmer; U_i = risk attributed to the error of the i[th] farmer; *i* = 1,2,3……n farmers.

Given the level of technology at disposal of the technical unit, stochastic frontier production function is expressed as the ratio of the observed output (Y^a) to the corresponding potential output (Y^p), as represented in equation [7].

$$T_e = \frac{Y^a}{Y^p} = \frac{f(X_{ij};\beta)+(V_i-U_i)}{f(X_{ij};\beta)+V_i} = \exp(U_i) \quad [7]$$

Where T_e is the technical efficiency, which ranges between 0 and 1, with 1 defining a fully efficient technical unit. The observed output (Y^a) represents the actual output while the potential output (Y^p) represents the frontier output level.

The explicit form of the imposed Cobb-Douglas frontier production function was calculated with equation [8].

$$lnY_i = ln\beta_0 + \sum \beta_k lnX_{ij} + (V_i - U_i) \quad [8]$$

Where Y_i = output of i[th] farmer (kg); X_i = vector of farm input used: X_1 = seeds (kg), X_2 = NPK fertilizer (kg), X_3 = urea fertilizer (kg), X_4 = herbicides (liter), X_5 = fuel (liter), X_6 = hired labor (man day), X_7 = family labor (man day), X_8 = irrigation water (gallon), X_9 = depreciation on capital items (*N*), and X_{10} = farm size (hectare); V_i = random variability in the production that cannot be influenced by the i[th] ffarmer (also known as uncertainty); U_i = deviation from potential output attributable to technical inefficiency (also known as risk). β_0 = intercept; β_k = vector of input parameters to be estimated; β_l = vector of output parameter to be estimated; *i* = 1,2,3……n farmers; *j* = 1,2,3………m inputs.

Conventional irrigation volume was calculated with equation [9].

$$\text{Conventional irrigation volume} = \left[\begin{array}{c}\text{(area irrigated per crop)}\\ \times\text{ (frequency or number of irrigation per month)}\\ \times\text{ (duration of irrigation given to crop in months)}\\ \times\text{ (number of hours given to each irrigation per day)}\\ \times\text{ (naverage yield borehole in gallon(s) per hour)}\end{array}\right] \Bigg/ 22{,}611 \quad [9]$$

The stochastic frontier cost function of the *i[th]* farmer (C_i) was calculated with equation [10].

$$C_i = f(P_{ij}, Y_{ij,}; \beta) + (V_i + U_i)\ (i = 1,2 \ldots\ldots n) \quad [10]$$

Where, P_i = vector of j^{th} input prices of the i^{th} farmer; Y_i = vector of the actual j^{th} output of the i^{th} farmer; β_i = parameter to be estimated; V_i = uncertainty which is beyound the control of the i^{th} farmer; and, U_i = risk which is attributed to the error of the i^{th} farmer. Positive signs preceded the two error terms because inefficiency is presumed to surge costs.

Given the level of technology and input prices at the disposal of a technical unit, the stochastic frontier cost function was expressed as the ratio of the actual cost (c^a) to the corresponding minimum cost, and it is given in equation [11].

$$C_e = \frac{c^a}{c^m} = \frac{f(P_{ij}, Y_{ij,};\beta) + (V_i + U_i)}{f(P_{ij}, Y_{ij,};\beta) + V_i} = \exp(U_i) \quad [11]$$

Where C_e represents the cost efficiency and takes values between 0 and 1, with 1 defining the most cost-efficient technical unit. The c^a represents the actual cost while c^m represents the frontier minimum cost level.

Stated below is the explicit form of the imposed Cobb-Douglas frontier cost function (equation [12]).

$$lnC_i = ln\beta_0 + \sum \beta_k lnP_{ij} + \beta_L lnY_i + (V_i + U_i) \quad [12]$$

Where, C_i = total of cost of i[th] farmer (*N*); P_i = vector of variable input prices: P_1 = cost of seeds (*N*), P_2 = cost of NPK fertilizer (*N*), P_3= cost of urea fertilizer (N), P_4 = cost of herbicides (*N*), P_5 = cost of fuel (*N*), P_6 = cost of hired labor (*N*), P_7 = cost of family labor (*N*), P_8 = cost of irrigation water (*N*), P_9 = depreciation on capital items (*N*), P_{10} = farm rental fee (*N*), P_{11} = wheat output (kg); *Vi* = random variability in the total production cost that cannot be influenced by the i[th] farmer (also known as uncertainty); *Ui* = deviation from minimum cost attributable to cost inefficiency (also known as risk). β_0 = intercept; β_k = vector of cost parameters to be estimated; β_L = vector of output parameter to be estimated; *i* = 1,2,3……n farmers; *j* = 1,2,3………m inputs.

The technical/cost inefficiency model was calculated with equation [13].

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 \ldots\ldots\ldots. + \delta_n Z_n \quad [13]$$

Where, Z_1 = Age (year); Z_2 = Gender (male = 1, female = 0); Z_3 = Marital status (married = 1, otherwise = 0); Z_4 = Educational level (year); Z_5 = Household size (number); Z_6 = Farming experience (year); Z_7 = Extension service (yes = 1, otherwise = 0); Z_8 = Credit access (yes = 1, otherwise = 0); Z_9 = Co-operative membership (yes = 1, otherwise = 0); Z_{10} = Mode of land acquisition (inheritance = 1, otherwise = 0); Z_{11} = Annual income (*N*); Z_{12} = Primary occupation (yes = 1, otherwise = 0); Z_{13} = Secondary occupation (yes = 1, otherwise = 0); δ_0 = intercept; and, $\delta_{(1-n)}$ = parameters to be estimated.

Using the generalized likelihood function, the test for the presence of technical/cost inefficiency is defined by λ as proposed by Sadiq et al. (2022b) (equation [14]):

$$\lambda = -2ln(\frac{H_0}{H_a}) \quad [14]$$

Where, H_0 corresponds to the value of the likelihood function for the unrestricted frontier [OLS] while H_a is the value of the likelihood function for the restricted Cobb-Douglas frontier model.

Thus, if the calculated Chi^2 is greater than the tabulated Chi^2 at a 5 % degree of freedom, then the null hypothesis is rejected in favor of the alternative hypothesis. The alternative hypothesis has approximately a mixed Chi^2 distribution with a degree of freedom equal to the number of parameters omitted in the unrestricted model, if the null hypothesis is true (Sadiq and Singh, 2016; Sadiq et al., 2021b, c), then the Economy of Scale can be calculated with equation [15].

$$ES = 1/\sum_{i=1}^{n} \frac{\partial lnTC}{\partial lnY} \quad [15]$$

Where $\partial lnTC/\partial lnY$ represents the partial logarithmic derivatives of the cost function concerning the logarithm of output. When all other variables are held constant, the sum of the various cost elasticities is the corresponding change in overall cost resulting from a small proportionate change in farm outputs. When the SE is greater than 1, a proportionate increase in output will result in a less-than-proportionate increase in total expenses, indicating the presence of economies of scale.

Total costs rise more than proportionately with an increase in outputs if the value estimated for Economies of scale is less than 1 and indicates diseconomies of scale. Inefficient scale is implied by farms working under reducing returns to scale.

The farm operates at the optimum production level if economies of scale equal 1, as evidenced by the presence of constant returns to scale, represented by its Economic Efficiency E_e (equation [16]).

$$Ee = Te * Ce \quad [16]$$

Economic efficiency ranges between < 1 and > 1. If E_e is < 1, it is called sub-optimal; if E_e = 1, it is called optimal economic efficiency; and, if E_e > 1, it is called supra-optimal economic efficiency.

3. Results and Discussion

3.1. Costs and return structures of wheat production

Results showed that the cost of cultivation cumulative total variable and fixed costs reached ₦ 693236.35, ₦ 634534.10, and ₦ 58702.25 respectively (Table 2). Of the cost of cultivation, the total variable cumulative fixed costs accounted for 91.53 and 8.47 % respectively. Disaggregation-wise, the cost incurred on NPK fertilizer was the highest (22.42 %), followed by seeds (20.72 %), and urea fertilizer (15.86 %); while the cost of irrigation water rate was the lowest (0.07 %). Nevertheless, the cost of production being ₦169.16, implied that to produce 1 kg of wheat output, a total of the aforementioned cost was incurred. Furthermore, the accumulated total revenue, gross margin, and net farm income per hectare were ₦1542983.16, ₦ 908449.10, and ₦ 849746.82 respectively. In the short and long-run, for every naira invested, the incurred cost, i.e., ₦ 1 is returned, and profits of 43 and 23 kobo (cents) respectively, were earned as evidenced by their respective ROI and ROCI indexes.

Table 2. Costs and return structure of wheat production per hectare.

Items	Unit (kg litre^{-1} gallon^{-1})	Unit price (₦ kg^{-1})	Total	%
Seed	160.80	893.46	143,668.60	20.72
NPK fertilizer	354.99	437.81	155,419.90	22.42
Urea	220.71	498.16	109,947.90	15.86
Herbicides	1.28	2177.48	2,779.67	0.40
Fuel	99.43	182.49	18,144.52	2.62
Hired labour	35.40	778.36	27,553.83	3.98
Family labour	175.241	562.72	98,610.53	14.23
Irrigation water	69,130.33	0.007	483.91	0.07
DCI*	1,041.36	1	1,041.36	0.15
Farm size	1	2,000	2,000	0.29
Interest on capital item		14 % of TVC	77,925.24	11.24
Managerial cost		10 % of TVC	55,660.89	8.03
Total variable cost			634,534.10	91.53
Total fixed cost			58,702.25	8.47
Total cost			693,236.30	
Total revenue	4,098.12	376.51	1,542,983.16	
Cost of production			169.16	
Gross margin			908,449.10	
Net farm income			849,746.82	
ROI			1.43	
ROCI			1.23	

* DCI = Depreciation on capital items

Based on the ROCI, it can be suggested that, at the prevailing interest rate of 14 %, for any advanced short-term credit given, *ceteris paribus*, the wheat farmers will be able to repay both the principal and the cost of credit and still make good profits. Therefore, it can be suggested that small-scale wheat farming in Jigawa State is not only profitable but a viable venture.

3.2. Technical efficiency of small-scale wheat farmers

Presented in Table 3 are the maximum likelihood estimates [MLE] of the parameters of the stochastic frontier production model derived as a function of wheat production. The estimated value of the sigma-squared estimate σ^2 = 0.128 at a 1 % probability level implied that the distribution assumed for the composite error term is correct and fits the specified equation. Besides, the significance of the gamma estimated coefficient = 0.6667 at 1 % probability level means unexplained systematic influences of the production function were the

Table 3. MLE of the stochastic frontier production function

Variable	Parameter	Coefficient	Standard error	t-statistics
Production model				
Constant	β_0	4.98424	0.927378	5.374***
Seed	β_1	0.083305	0.042509	1.960**
NPK fertilizer	β_2	0.120008	0.072574	1.653*
Urea	β_3	-0.12375	0.069039	1.792*
Herbicides	β_4	-0.0665	0.052028	1.278^{NS}
Fuel	β_5	0.632428	0.14752	4.287***
Hired labor	β_6	-0.08279	0.04346	1.905*
Family labor	β_7	-0.00515	0.077985	0.066^{NS}
Irrigation water	β_8	0.023422	0.017606	1.330^{NS}
DCI	β_9	0.026159	0.018828	1.389^{NS}
Farm size	β_{10}	0.247658	0.13989	1.770*
Inefficiency model				
Intercept	δ_0	-10.5144	3.712438	2.832***
Age	δ_1	0.00036	0.007589	0.047^{NS}
Gender	δ_2	-0.52632	0.148147	3.552***
Marital status	δ_3	0.02132	0.106362	0.200^{NS}
Education	δ_4	0.012198	0.009641	1.265^{NS}
Household size	δ_5	-0.03427	0.013927	2.460**
Farming experience	δ_6	-0.02302	0.013371	1.721*
Extension contact	δ_7	0.288637	0.212559	1.357^{NS}
Credit access	δ_8	-0.03169	0.44067	0.071^{NS}
Co-operative membership	δ_9	-0.98091	0.244863	4.005***
Land ownership	δ_{10}	-0.16425	0.133693	1.228^{NS}
Annual income		0.713469	0.248445	2.871***
Primary occupation		0.528775	0.307367	1.720*
Secondary occupation		0.206246	0.170634	1.208^{NS}
Sigma-squared	σ^2	**0.128424**	**0.015255**	**8.418*** **
Gamma	γ	**0.666693**	**0.06407**	**10.41*** **
LR test		**38.44094**		

***, **, *, & ^{NS} mean significance at 1, 5, 10 % and non-significant respectively.

dominant sources of the random error. In a nutshell, it means there is a case of one-sided error. i.e., human risk affects the technical efficiency of wheat farmers in the study. Results show that 66.67 % of the variation in total wheat production among farmers was due to differences in their technical efficiencies, *i.e*. risk associated with idiosyncratic factors, while 33.33 % corresponds to uncertainty (unexplained variation). Nevertheless, the calculated Likelihood Ratio [LR] test estimate (38.44) was greater than the tabulated LR test (33.92) at 22 degrees of freedom (5 % probability level), meaning that traditional ordinary least square [OLS] cannot adequately represent the data, thus the MLE Cobb-Douglas stochastic frontier production function is the best form to represent the data obtained. Therefore, it can be inferred that the MLE Cobb-Douglas stochastic frontier production function fits the specified equation, thus the estimated parameters are reliable for future predictions with efficiency, accuracy, and consistency.

As evident from the production function model, except for herbicides, family labor, irrigation water, and depreciation on capital assets, all the remaining production variables had a significant influence on wheat production, as indicated by their respective estimated coefficients that were different from zero at 10 % probability level (Table 3). Variables *viz*. seeds, NPK fertilizer, fuel, and farm size positively influenced wheat output, while urea fertilizer and hired labor negatively influenced wheat output. The positive and significant coefficient of seeds in the model is an indication of the adoption and effective utilization of improved wheat seed varieties in the study area, which may have increased wheat output. In addition, except in cases of overcrowding, which is likely to stimulate competition for available nutrient uptake with dire consequences of a decrease in output, high seed rates would result in higher wheat output in the study area. Thus, an increase in the use of seeds by 1 kg may increase wheat output by 0.08 %. Similar findings were established by Hailekiros et al. (2018) and Asfaw et al. (2019) in their various study areas; whereas Dessale (2019), found a contrary result in his study area.

The positive-significant effect of NPK fertilizer indicated its effectiveness in improving soil quality due to the poor composition of these macronutrients in regular soils, thus its application increased wheat output. Thus, it can be inferred that the use of composite fertilizer increases the productivity of the operational holding cultivated for wheat farming. However, given the improvement of soil quality due to NPK fertilizer, the paddle soils required little or no urea fertilizer, explaining the significantly negative effect of the latter coefficient on output. In addition, the negative effect of urea fertilizer showed a tendency of nitrogen loading in the soil due to its excess, thus reducing the effect on wheat output. Therefore, for every 1 kg increase in compound and single fertilizers, wheat output will increase and decrease respectively by approximately the same percent (0.12 %). This finding is contrary to Hailekiros et al. (2018) who found a direct relationship between urea fertilizer and wheat output. The positive-significant effect of fuel indicated the judicious use of fuel in powering irrigation pumping machines, thus increasing wheat output due to improvements in land productivity. Thus, for a 1-liter increase in fuel, wheat output was expected to increase by 0.63 %.

Further, the positive-significant effect of farm size indicated farmers explored economies of size in wheat production, thus increasing its output. However, this may be associated with a lower pressure on limited arable cropland due to reduced irrigation crop activities during the *Harmattan* period, when wheat is cultivated. Thus, for a unit increase in farm size by 1 hectare, wheat output will increase by 0.25 %. This finding conforms to what Hailekiros et al. (2018); Dessale (2019); Asfaw et al.(2019); and, Tleubayev et al. (2022) reported in their various study areas. Nevertheless, the negative-significant coefficient reported by the hired labor variable implied excess use of paid labor due to poor substitution effects of herbicide use, thus decreasing wheat output. This mismatch didn't only make herbicides used insignificant but also decreased wheat output as evidenced by its negative estimated coefficient. The implication is that, for every liter increase in herbicides, wheat output will decrease by 0.067 %. The non-significant but negative coefficient for family labor may be attributed to the deployment of excess free family child labor because of migrant labor by able-bodied household members to the city for white-collar jobs during the dry season. Likewise, the non-significant but positive coefficients for irrigation water and depreciation on capital items may not be unconnected to the inadequate water supply and use of rudimental farm implements respectively. The return to scale [RTS] coefficient was 0.855, implying that farmers are operating within the economic rational stage of production (i.e., stage II) which will guarantee profit optimization keeping in view cost minimization for the technical unit of production. Besides, the average productivity of production variables was greater than their respective marginal productivities justifying the idea of a rational stage of production operation for wheat farmers in the study area [Table 4]. Since perfect market characteristics exist in wheat production in the study area, thus it implied that farmers are price-takers. Contrary findings were established by Dessale (2019) and Asfaw et al. (2019) in their various study areas.

Table 4. Average (APP) and marginal (MPP) physical products.

Inputs	Average estimate	APP	MPP
Seed	283.30	25.49	2.12
NPK fertilizer	625.44	11.54	1.39
Urea	388.85	18.57	-2.30
Herbicides	2.25	3,210.30	-213.47
Fuel	175.18	41.22	26.07
Hired labor	62.37	115.77	-9.59
Family labor	308.74	23.39	-0.12
Irrigation water	121,796.4	0.06	0.001
DCI	9,173.57	0.79	0.020
Farm size	1.76	4,098.12	1,014.93

For the technical inefficiency model, gender, household size, farming experience, cooperative membership, annual income, and primary occupation were variables that significantly influenced the technical efficiency of wheat farmers, as evidenced by their respective coefficients that were different from zero at a 10 % probability level (Table 3). It was observed that variables related to gender, farming experience, household size, and cooperative membership tended to decrease technical inefficiency, while annual income and primary occupation variables increased technical inefficiency as evidenced by the negative and positive signs for the former and latter respectively. The negative and significant coefficient for gender implied that male farmers tend to be technically more efficient than women, and this might not be unconnected to gender discrimination and stereotypes entrenched by cultural and religious barriers that limit women's access to productive resources. As reported by Sadiq et al.(2021d); and National Institute of Agricultural Extension Management (MANAGE, 2020), if women are provided with the same access to productive resources as men, they could boost yield by 20-30 %, thus raising the overall agricultural output in developing countries by 2.5-4 %. This gain in production might lessen the number of hungry people in the world by 12-17 % (Sadiq et al., 2021d; MANAGE, 2020). So, the future of agriculture is likely to be in the hands of farm women, but Nigerian society has yet to recognize women as 'farmers' rather than 'wives' of the farmers (Sadiq et al., 2021e; 2022c, d). Thus, women farmers are likely to have an increase in their technical inefficiency (0.526) compared to men. Due to the underappreciation of women's contributions in the field of study, they are likely to receive less support in wheat development programs. This outcome aligns with the conclusion reached by Asfaw et al. (2019) in their research.

Significantly negative coefficients reported for household size imply that farmers with relatively large households appropriately utilize free-cheap family labor against their counterparts with small household sizes, thus decreasing their technical inefficiency. In other words, it points to access to free family labor of good quality that was judiciously deployed among the farmers that maintained a large household size and assisted in decreasing their technical inefficiency in wheat farming against their counterparts that maintained a relatively small household size. Besides, family members' remittance from other income sources buffers farm capital stream, which consequently stimulates business, especially for farmers that maintain a non-vulnerable large household size, which is a likely contributory factor to the achieved increased technical efficiency. Thus, for a unit increase in a farming household by 1 able-bodied person, technical inefficiency reduced by 0.034 percent. The negative and significant effect of the farming experience coefficient indicates that farmers with adequate years of experience tend to be technically more efficient compared to their counterparts with fewer years of farming experience in wheat production. Adequate experience is a catalyst that enhances managerial efficiency which is very important for a farmer to achieve economic efficiency. As the average farming experience was 13.8 years, it can be inferred that wheat production is not an emerging enterprise in the study area, thus a need for more private investment as it possesses vast potential for penetration into the global wheat market supply chain which is presently being contracted because of Russian and Ukraine impasse and the American cold war on wheat markets. Results indicate that for every unit increase in the farming experience of a farmer by one year, technical inefficiency was likely to reduce by 0.023 %.

The negative and significant effects of cooperative membership indicate that farmers who explored social capital pooling tend to be technically more efficient than their counterparts who failed to participate in such endeavors. Pooling of social capital by being a member of a cooperative association can be valuable for small-scale operations because of its pecuniary economic advantages, such as access to secure markets, bargaining power in output markets, bulk discounts in input purchases, and technical assistance which enhances technical efficiency. Thus, farmers who have membership in a cooperative association are likely to experience a decrease in their technical inefficiency by 0.981 % against their counterparts who didn't belong to a cooperative association. The positive and significant effect of the annual income coefficient implied that farmers with large income streams tend to be susceptible to technical inefficiency owing to a pressing need for materialistic fortune-capital consumption.

In African agrarian settings, it is a common phenomenon, especially among male farmers, either to spend on personal things or re-invest in agricultural productivity when they earn more cash. Therefore, for a percent increase in a farmer's income, his/her technical inefficiency will increase by 0.714 %. The positive and significant coefficient of primary occupation implied that farmers who did not take up wheat farming as a primary occupation tended to be technically inefficient, and this might be attributed to paying less attention to wheat farming or wheat farming not being considered a serious business, thus affecting the farm's technical efficiency. Thus, farmers who take up wheat farming as a non-primary occupation are likely to experience an increase in their technical inefficiency by 0.53 % against their counterparts who have wheat farming as a primary occupation.

A summary of technical efficiency scores presented in Table 5 showed that, on average, wheat farmers performed at a technical efficiency score of 90.61 %, thus implying that the actual output of an average farm in the study area is 9.39 % short of the potential (optimum) output defined by the frontier surface. These results imply that, there is still room for an average farm to bridge the gap between the actual output and potential output by increasing its technical efficiency by 9.39 %. The mean technical efficiency reported (93.34 %) is higher than the average technical efficiency scores observed by other researchers in their various studies (Asfaw et al., 2019; Dessale, 2019; Hailekiros et al., 2018; Tleubayev et al.,2022). However, frequencies of occurrence of predicted technical efficiency between 0.90-0.99 been 71.7 %, implied that most farmers were efficient in optimizing output subject to input constraints at the prevailing production technology. The most and least efficient farmers operated at 97.33 and 40.05 % efficiency levels respectively. For the most and least efficient farmers to be on the frontier surface, they need to increase their technical efficiency by 2.67 and 39.05 % respectively.

Table 5. Technical efficiency score distribution of small-scale wheat farmers

Efficiency level	**Frequency**	**Percentage**
0.40-0.49	2	0.7
0.50-0.59	5	1.8
0.60-0.69	4	1.4
0.70-0.79	1	0.4
0.80-0.89	68	24.0
0.90-0.99	203	71.7
Total	283	100.0
Minimum	0.400455	
Maximum	0.97327	
Mean	0.90606056	
Mode	0.933407	
Standard deviation	0.079968	

However, for the average and least efficient farmers to be on par with the best (reference peer) efficient farmers, they need to increase their technical efficiency by 9.65 and 61.60 % respectively. Individual-wise, the potential wheat output lost by the most (DMU 265), average and least (DMU 22) efficient farmers were approximately 390, 748.17 and 2994.32 kg respectively (Table 8). The entire results can be provided on request). Given the prevailing state of technology in the study area, it can be inferred that farmers still have room to increase their efficiency in wheat farming as an efficiency void/gap of approximately 9.39 % from the optimum remains yet to be achieved by most farmers.

3.3. Cost efficiency of small-scale wheat farmers

The MLE of the parameters for the stochastic frontier cost function showed both sigma-squared and gamma coefficients to be within the acceptable margin of 10 % error gap (Table 6). The significance of the former implied the correctness of the distribution assumed for the composite error term and the goodness of fit of the model for the specified equation. For the latter, it implies there is a presence of cost inefficiency and induced human risk accounted for 99.98 % variation in total production costs among farmers while a marginal percent of 0.02, owing to uncertainty, is a situation beyond farmers' control. Furthermore, at 5 % probability level of 23 degrees of freedom, the tabulated LR test (35.172) was less than the calculated LR test (215.9717), which implies that the traditional response function (OLS) is not an appropriate method for estimation of the data, but rather the MLE, thus justified the validity of the method of estimation applied. Therefore, based on these diagnostic statistics, it can be inferred that the MLE estimated parameters of the stochastic frontier cost function are reliable for future prediction with certainty, consistency, efficiency, and accuracy.

Table 6. MLE of stochastic frontier cost function.

Variable	Parameter	Coefficient	Standard error	t-statistics
Cost model				
Constant	β_0	1.528186	0.126962	12.03***
Seed	β_1	0.297625	0.011191	26.59***
NPK fertilizer	β_2	0.398973	0.0222	17.97***
Urea	β_3	0.006281	0.02066	0.304^{NS}
Herbicides	β_4	-0.00877	0.002501	3.504***
Fuel	β_5	0.021854	0.011917	1.833*
Hired labor	β_6	0.052083	0.006057	8.598***
Family labor	β_7	0.199153	0.013366	14.90***
Irrigation water	β_8	0.093068	0.004819	19.31***
DCI	β_9	0.005801	0.002109	2.750***
Farm size	β_{10}	-0.07999	0.011794	6.782***
Output	β_{10}	0.00657	0.006066	1.083^{NS}
Inefficiency model				
Intercept	δ_0	4.43238	1.047636	4.230***
Age	δ_1	0.012688	0.004108	3.088***
Gender	δ_2	0.231219	0.0595	3.886***
Marital status	δ_3	0.307329	0.05339	5.756***
Education	δ_4	-0.0116	0.004626	2.506**
Household size	δ_5	0.095606	0.012511	7.641***
Farming experience	δ_6	-0.02483	0.005088	4.879***
Extension contact	δ_7	0.612352	0.082157	7.453***
Credit access	δ_8	-0.85503	0.20508	4.169***
Co-operative membership	δ_9	-0.16442	0.048202	3.411***
Land ownership	δ_{10}	0.095902	0.041472	2.312**
Annual income	δ_{11}	-0.59689	0.102377	5.830***
Primary occupation	δ_{12}	-0.6299	0.105034	5.997***
Secondary occupation	δ_{13}	0.182334	0.054266	3.360***
Sigma-squared	σ^2	**0.260089**	**0.032109**	**8.100*** **
Gamma	γ	**0.999822**	**8.5E-05**	**11763.86*** **
LR test			**215.9717**	

***, **, *, & ^{NS} mean significance at 1, 5, 10 %, and non-significant respectively.

Results of the cost function model showed that total cost is significantly influenced by costs of seeds, NPK fertilizer, herbicides, fuel, hired labor, family labor, irrigation water, depreciation on capital items and rental fees as evidenced by their respective estimated coefficients that were different from zero at 10 % probability level (Table 6). Except for the costs of herbicides and rental fees, all remaining items positively influenced total cost. The negative and significant effect of herbicide cost may be attributed to its substitution effect on utilized labor, while rental fees may be associated with the effect of economies of scale. Nevertheless, the non-significant effect of urea fertilizer might be attributed to a lesser use due to adequate utilization of compound fertilizer (NPK), while the non-significant coefficient of output might be related to yield gap variation among most farmers. Therefore, cost elasticities of seeds, NPK fertilizer, fuel, hired and family labor, irrigation water, and annual capital depreciation implied that an increase in each of the respective cost items will increase total production cost. That is, a 1 percent increase in the respective costs of seeds, NPK fertilizer, fuel, hired labor, family labor, and annual capital depreciation will increase total production costs by approximately 0.30, 0.40, 0.02, 0.05, 0.20, 0.09, and 0.06 % respectively. Whereas, a 1 % increase in the costs of herbicides and rental fees will decrease total production costs by approximately 0.09 and 0.08 % respectively. However, the positive values for coefficients related to capital cost (costs of seeds, NPK fertilizer, fuel, irrigation water, and annual capital depreciation) and labor cost (hired and family labor) mean that the cost function monotonically increases with input prices.

Furthermore, it was established that diseconomies of scale prevailed among farmers as evidenced by the reported value for the economies of scale index (ES) (0.0067) which is less than 1. This value implies that, despite farmers being in the rational region of production they are experiencing diseconomies of scale, which may be attributed to poor resource status that characterized smallholder farmers in the study area compared to medium-large scale farmers that had a better chance to explore pecuniary advantages to achieve economies of scale. This finding contradicts Schultz's poor but efficient hypothesis that peasant farmers in a conventional agricultural setting are efficient in their resource allocation given their operating circumstances (Sadiq & Singh, 2016). A review of the cost inefficiency model in Table 6 showed all variables associated with human risk had a significant influence on farmers' cost efficiency as evidenced by their respective parameter estimates that were different from zero at a 10 % probability level. It was observed that education, farming experience, access to credit, cooperative membership, annual income, and primary occupation decreased cost inefficiency, as evidenced by their negative coefficients while age, gender, marital status, household size, extension contact, land acquisition and secondary occupation increased cost inefficiency as indicated by their positive coefficients in the model.

The negative and significant coefficient of education implies that educated farmers tend to be cost-efficient which may be attributed to exploration of skills and source for valid economic information, thus increasing overall farm efficiency. Thus, if a farmer's educational level increases by a year, cost inefficiency will decrease by 0.012 %. The negative and significant coefficient of farming experience entailed that farmers with adequate years of experience tend to be cost-efficient, which may be related to an efficient allocation of resources that optimize profit and minimize costs in wheat production. Thus, for a 1-year increase in a farmer's farming experience, cost inefficiency will decrease by 0.025 %. The negative and significant effect of access to credit means that farmers with access to credit tend to be cost-efficient, which may be associated with timely access to procurement of farm inputs, thus ensuring seamless farm operation that will decrease cost inefficiency. Therefore, the probability of a decrease in cost inefficiency of farmers with access to credit facilities will be 0.855 % against their counterparts with no access to credit facilities. The negative and significant coefficient of the co-operative membership coefficient means that farmers who belong to co-operative associations tend to be cost-efficient, which may relate to pecuniary advantage, viz. the benefits of bulk discount in input purchase, technical and advisory supports, etc., thus decreasing cost inefficiency. Thus, farmers that belong to co-operative associations are likely to experience a decrease in cost inefficiency by 0.1644 % when compared to their counterparts that didn't belong to co-operative associations. The negative and significant coefficient related to annual income implies that large-income farmers tend to be more cost efficient probably due to re-investment in farm business rather than capital consumption. Therefore, if a farmer's income increases by 1 percent, cost inefficiency will decrease by 0.597 %. The negative and significant coefficient of primary occupation implies that farmers who take up wheat farming as their primary occupation tend to be cost efficiency, and this may be attributed to their meticulous investment in wheat farming as a business for livelihood sustenance. Therefore, farmers who take up wheat farming as a primary occupation are likely to experience a decrease in cost inefficiency by 0.630 % versus their counterparts who consider wheat farming as a secondary occupation.

The positive and significant effect of age implies that older farmers tend to be cost-efficient, which might be associated with an increased marginal cost of labor due to the expected consequence of the decline in productivity with age. Besides, the consequence of old age on technical know-how/skills is a likely contributing factor that may affect the economic rationality of old-aged farmers, thus affecting their cost efficiency. Thus, for a unit increase in the age of a farmer by 1 year, cost inefficiency will increase by 0.013 %. The positive and significant coefficient for gender implies women farmers tend to be cost-inefficient and this may be attributed to lower access to productive resources due to gender discrimination and stereotypes that owed to religious and cultural barriers. Thus, female farmers incur a cost inefficiency increase of 0.231 % when compared to male farmers. The positive and significant effect of marital status showed that unmarried farmers tend to be cost-inefficient, which might be attributed to poor access to the paired benefits of economic and social capital inherent in marriage. Therefore, being an unmarried farmer, is likely to increase cost inefficiency by 0.307 %, more than that of married farmers. The positive and significant coefficient of household size showed that farmers with vulnerable large household sizes tend to be cost-inefficient, and this might be attributed to extra costs incurred on household expenditure and paid labor for farm operation. Thus, an increase in a farm family by 1 person will lead to an increase in cost inefficiency by 0.096 %. The positive and significant effect of extension contact showed that farmers with no extension contact tend to be cost-inefficient, which may be attributed to a lack of advisory guidance on rational economic resource mix, poor access to innovative technologies, etc. Therefore, for farmers with no access to extension contact, wheat production is likely to experience an increase in cost inefficiency by 0.612 % compared to their counterparts with access to extension services. The positive and significant coefficient of land acquisition shows that farmers whose title of land ownership is physical other than legal, tend to be cost inefficient, and this might be attributed to their inability to harness the land economically due to lack of permits when compared with farmers with legal ownership: cultural value other than economic value is attributed to land by the community. Therefore, the lack of legal ownership of land is likely to increase the cost inefficiency of such farmers by 0.096 % against their counterparts with a legal title of ownership. In this sense, it is common in Africa to hear a man being referred to as the son of the soil. The positive and significant effect of secondary occupation showed that farmers who take up wheat farming as a secondary occupation tend to be cost inefficiency, mainly due to poor investment and management of the business. Therefore, farmers who engaged in wheat farming as a secondary occupation, are likely to experience an increase in cost inefficiency by 0.182 % when compared to their counterparts who engaged in wheat farming as a primary occupation.

Table 7. Cost efficiency score distribution of small-scale wheat farmers

Efficiency level	Frequency	Percentage
1.00	-	-
1.01-1.09	201	71
1.10-1.19	44	15.5
1.20-1.29	23	8.1
1.30-1.39	8	2.8
1.40-1.49	2	0.7
1.70-1.79	2	0.7
>=2.00	2	0.7
>=3.00	1	0.4
Total	283	100.0
Minimum	1.002298	
Maximum	3.616334	
Mean	1.1125220	
Mode	1.01	
Standard deviation	0.216242	

The summary of cost efficiency scores presented in Table 7 showed the estimated mean cost efficiency of sampled farms was 1.11. This means that an average farm incurred a cost that is 11 % above the minimum cost defined by the cost frontier. In other words, it implies that an average farm incurred an extra cost of 11 % relative to best-practice farms facing the same technology and producing the same wheat. Besides, the frequencies of occurrence of predicted cost efficiency between greater than 1 but less or equal to 1.19 is 86.6 %, implying that most sampled farms were fairly efficient in producing wheat at a given output level using cost-minimizing input, which reflects the farmers' tendency to contain wastage of resources linked to production from the cost's point of view. The most frequently occurring efficiency score was 1.01, while the best and worst efficient farms recorded efficiency scores of 1.002 and 3.616 respectively. Therefore, for farms with an average and worst efficiency, to attain the status reflected by best practice farms (i.e. more allocative efficient farms), they need to reduce costs by 11.24 and 261.03 % respectively. However, for best, average, and less efficient farms to be on the cost efficiency frontier (i.e., allocative efficiency), they need to prune down total production costs by 0.23, 11.27, and 261.63 % respectively. Furthermore, the best (DMU 50) and least (DMU 66) efficient farms incurred extra costs of ₦2174.25 and ₦5039762 respectively, while the average efficiency farms incurred an extra cost of ₦123636 (Table 8).

Table 8. Output and cost gaps of small-scale wheat farmers.*

Firm	TE	CE	Output(A)	TC (A)	Output (P)	TC (Min)	Output (G)	Cost (E)
DMU 1	0.947897	1.09395	4,000	542,275.4	4,219.866	495,703.9	-219.866	46,571.53
DMU 2	0.636494	1.179981	5,000	1,906,804.0	7,855.535	1,615,962.0	-2,855.53	290,842.1
DMU 3	0.965168	1.032887	10,000	605,217.7	10,360.89	585,947.8	-360.891	19,269.95
DMU 4	0.55122	1.013854	4,000	978,667.4	7,256.632	965,294.6	-3256.63	13,372.81
DMU 5	0.926776	1.019393	5,000	566,943.5	5,395.047	556158.1	-395.047	10,785.41
DMU 6	0.923111	1.046872	3,000	457,132.4	3,249.881	436665.2	-249.881	20,467.15
DMU 7	0.945552	1.044968	4,000	457,233.7	4,230.332	437557.8	-230.332	19,675.88
DMU8-21	-	-	-	-	-	-	-	-
DMU 22	0.400455	1.012435	2,000	914,183.5	4,994.325	902955.7	-2,994.32	11,227.8
DMU 23-49	-	-	-	-	-	-	-	-
DMU 50	0.896661	1.002298	8,000	948,281.8	8,921.985	946107.6	-921.985	2,174.25
DMU 51-65	-	-	-	-	-	-	-	-
DMU 66	0.582312	3.616334	4,700	6,966,030.0	8,071.278	1,926,269.0	-3,371.28	5,039,762.0
DMU 67-264	-	-	-	-	-	-	-	-
DMU 265	0.97327	1.027292	14,200	557,201.9	14,590.0	542,398.8	-389.996	14,803.04
DMU 266-279	-	-	-	-	-	-	-	-
DMU 280	0.947367	1.040401	4,000	557,227.2	4,222.228	535,588.9	-222.228	21,638.33
DMU 281	0.90329	1.091989	4,000	535,237	4,428.256	490,149.0	-428.256	45,088.07
DMU 282	0.949661	1.168946	8,000	2,274,788.0	8,424.055	1,946,017.0	-424.055	328,771.4
DMU 283	0.907382	1.378501	4,000	997,735.7	4,408.287	723,783.2	-408.287	273,952.5
Mean	0.906061	1.112522					-724.648	147,674.2
Min	0.400455	1.002298					-142.382	2,174.25
Max	0.97327	3.616334					-3,536.47	5,039,762.0

* DMU = Decision making unit; A = Actual; P = Potential; TC = Total cost; Min = Minimum; G = Gap; E = Excess.
Note: The entire results can be produced on request.

3.4. Economic Efficiency of Wheat Farmers

An overview of economic efficiency scores showed that a majority (58.3 %) of farmers operated at sub-optimal levels, while 41.7 % operated at supra-optimal levels (Table 9). The most occurring economic efficiency was 0.972, while the highest, average and least economic efficiency scores were 2.35, 1.01, and 0.405 respectively. Though, the average is supra-optimal, it operates very close to the optimal frontier level. Therefore, for the supra-optimal farm to attain an optimal economic efficiency level, it needs to reduce its cost by 134.84 % while for the sub-optimal farm to attain an optimal economic efficiency level, it needs to increase its technical output by 59.46 %. Nevertheless, for the average farm to be optimally efficient, it needs to cut down its cost by 0.65 %.

Table 9. Economic efficiency score distribution of small-scale wheat farmers

Efficiency level	Frequency	Percentage
0.400-0.499	2	0.7
0.500-0.599	4	1.4
0..600-0.699	2	0.7
0.700-0.799	3	1.1
0.800-0.899	26	9.2
0.900-0.999	128	45.2
1.00	0	0
>1.00	118	41.7
Total	283	100.0
Minimum	0.405434	
Maximum	2.348403	
Mean	1.006652	
Mode	0.972051	
Standard deviation	0.184504	

3.5. Constraints Affecting Wheat Production

Results in Table 7 show that the farmers perceived high costs of farm inputs (1st), high costs of processing (2nd), paucity of finance (3rd), price fluctuations (4th), and inadequate processing materials (5th) as the most severe constraints affecting wheat production, as evident by their respective mean values, that were greater than the mean threshold value of 3.5. Except for the communal system of land ownership and high costs of improved crop varieties/technologies which were perceived not to be a severe challenge, all the remaining constraints were considered by farmers to be less severe challenges confronting wheat production in the study area. The grand mean (3.10) being less than the Likert scale threshold mean (3.5), indicates farmers have less perception of the severity of challenges affecting wheat production, thus supporting forgoing findings on farmers' perceptions of the challenges faced. Additionally, the perception index (0.52) means that most farmers (52 %) perceived challenges affecting wheat production to be less severe. Furthermore, the reported value of Kendall's coefficient of concordance (0.568), implies there is a moderate agreement among farmers concerning the ranking of challenges plaguing wheat production in the study area. In addition, the significance of Freidman's Chi-square test statistic at 1 % justified that the ranking of constraints comes from the statistical population. Therefore, the study advises policymakers to possibly conform to the ranking in addressing some of the challenges confronting wheat production in the study area.

To determine constraints affecting wheat production in the study area, the 28 assessed variables were subjected to a varimax rotation of Principal Component Analysis, from which it extracted four principal components to represent the challenges affecting wheat production in the study area, as evident by their respective eigenvalues that were not less than 1.00 (Table 10). These four components accounted for 79.69 % of the total variation, a value that is satisfactory in social science studies as reported by Sadiq et al. (2017). Furthermore, the value obtained for the Kaiser-Meyer-Olkin [KMO] test (0.892) was above the acceptable threshold (0.5) as recommended by Kaiser (1974); and fell in the category of being "great (Hutcheson & Sofroniou, 1999)/ meritorious (Sadiq et al., 2018a, b, c)", indicating a compact pattern of correlation among the constraints; therefore, the exploratory factor yielded different and reliable factors. Additionally, there is a common factor, thus the sampling adequacy of the data for the exploratory factor analysis. The significance of Bartlett's test of Sphericity at less than a 1 % error gap means that the R-matrix (rotation matrix) is not an identity matrix. Moreover, the reliability of the test statistic indicated that there is internal consistency in each of the identified factors, as evident by their respective Cronbach's Alpha test statistics that were greater than the recommended threshold value of 0.70 as reported by Sadiq et al. (2018a, b, c).

Table 10. Constraints affecting small-scale wheat production.*

Constraints	Mean	F1	F2	F3	F4
High costs of farm inputs (Machinery/Implements, fertilizers, herbicides, labor etc.). (C1)	5.57 (1st)	0.898			
Inadequate finance (C2)	4.46 (3rd)	0.943			
Price fluctuation (C3)	4.38 (4th)	0.905			
Lack of standard unit of measurement (C4)	2.74 (18th)	0.868			
High cost of processing (C5)	4.81(2nd)				0.623
Problem of poaching/theft of produce (C6)	3.94 (6th)			0.817	
Inadequate processing materials (C7)	4.01 (5th)	0.611		0.459	0.436
Inadequate of extension services (C8)	3.15 (7th)	0.421	0.584		0.528
Inadequate storage facilities (C9)	3.10 (9th)	0.492	0.534		0.528
High illiteracy level (C10)	2.92 (14th)			0.753	
Labor scarcity & supply problem (C11)	2.36 (23rd)		0.687		0.424
Poor road network (C12)	2.99 (13th)	0.432	0.476		0.492
Poor access to market information (C13)	3.08 (10th)	0.540	0.539		0.437
Cultural influence on access and use of some technologies (C14)	3.06 (11th)	0.547	0.481		0.496
Communal system of land ownership (C15)	1.87 (26th)			-0.643	0.453
Difficulty in leasing /renting of farmlands (C16)	2.78 (17th)			0.827	
Scarcity of farm inputs (C17)	2.40 (22nd)				0.678
Limited/inadequate quantities of improved crop yield (C18)	2.71 (21st)			0.859	
High cost of improved crop varieties/technologies (C19)	1.82 (27th)			-0.700	
Lack of access to improved crop varieties (C20)	2.72 (20th)			0.876	
Abiotic and biotic stresses (C21)	2.73 (19th)				0.833
Increased rural urban migration (C22)	3.08 (10th)	0.505	0.530		0.459
Low public and private investments (C23)	2.86 (15th)		0.868		
Climatic change problem (C24)	2.81 (16th)		0.890		
Problem of trade restriction (C25)	2.07 (25th)		0.881		
Unfavorable exchange rate (C26)	2.08 (24th)		0.893		
Inadequate of incentives to farmers (C27)	3.14 (8th)	0.619	0.427		0.494
Inadequate of access to water (C28)	3.05 (12th)	0.639	0.501		
Grand mean	**3.10**				
Perception index	**0.52**				
Freidman's statistics	**4,336.41*** **				
Kendall' coefficient of concordance	**.568 (4,336.41)*** **				
Eigen value		**14.126**	**4.126**	**2.722**	**1.339**
Variance %		**50.449**	**14.735**	**9.721**	**4.782**
Cronbach's Alpha		**0.955**	**0.950**	**0.941**	**0.752**
KMO		**0.892**			
Bartlett's Test of Sphericity		**(1,0647.92)*** **			

* Value in parenthesis corresponds to Chi^2; C means constraint, Mean benchmark is 3.5; Grand mean is = sum of mean divided by the total number of statements; the Perception index = the grand mean divided by the highest Likert scale value (Sadiq et al. 2018c).

For extracted factors, loadings whose absolute values were less than 0.40 were automatically dropped as proposed by Sadiq et al. (2017, 2018a, b, c). The extracted factors affecting wheat production were labeled as follows in order of variance explained: price constraint, technical/technological constraint, managerial constraint, and infrastructural constraint. The factor related to price constraint accounted for 50.45 % of the total variation, evidencing farmers' concern about the high cost of farm inputs, inadequate finance, price fluctuations, lack of standard of unit of measurement, inadequate processing materials, poor access to market information, cultural influence on access and use of technologies, inadequate provision of incentives and poor access to irrigation water. The second factor, which corresponded to technical/technological constraints, accounted for 14.74 % of the total variation. It showed the respondent's concern about poor extension services, inadequate storage facilities, labor scarcity, increased rural-urban migration, low public and private investments, climate change problems, trade restriction problems, and unfavorable exchange rates. The third factor, labeled "managerial constraint", which accounted for 9.72 % of the total variation, showed farmers' concern about problems related to produce poaching/theft, high illiteracy levels, difficulty in land leasing, high costs of improved crop varieties, and inadequate access to improved crop varieties. Finally, factors corresponding to infrastructural constraint accounted for 4.78 % of the variation, showing the farmers' concerns regarding high costs of processing, scarcity of farm inputs, and abiotic-biotic stresses.

Furthermore, the effects of the extracted constraints, namely managerial efficiency - a mediating factor on technical and cost efficiency-, were verified using confirmatory factor analysis [CFA] (Table 11 and Figure 1). Structurally, all constraints influence managerial efficiency, a mediating factor, as evident by the estimated parameters that were plausible at a 10 % probability level. The positive-significant effect of managerial (F3) and infrastructural (F4) constraints, implies they have a less severe input on the managerial efficiency of farmers, while the negative-significant coefficients for price (F1) and technological (F2) constraints, mean these variables are highly severe challenges that affect managerial efficiency (ME) of wheat farmers. In other words, challenges of F3 and F4 will encourage farmers to resolve their managerial efficiency by exploring other potential opportunities to wade their hindrance on-farm economic efficiency while challenges of F1 and F2 affect the structural farm plans of wheat farmers. Thus, if a farmer is challenged by price and technological constraints, his/her managerial efficiency is likely to plummet by 1.9 and 2.9 % respectively, whereas, challenges of managerial and infrastructural constraints have the likelihood of increasing the managerial efficiency of a farmer by 0.9 and 1.6 % respectively. Though not significant, the high severity of price and technological constraints on managerial efficiency made the latter negatively affect the cost efficiency [CE] of wheat farmers in the study area. Contrarily, significantly, it was observed that cost inefficiency negatively affects the economic efficiency of wheat farmers, as evidenced by its coefficient that is different from zero at a 10 % probability level. Thus, farmers' economic efficiency [EFFP] is likely to decline for any unit increase in cost inefficiency, and this is not unconnected with the transient effects of F3 and F4 constraints, highly severe constraints on managerial efficiency that weaken cost efficiency, thus affecting economic efficiency of wheat farmers in the study area. Therefore, for long-run sustainable wheat production in the study area, we suggest policymakers pay more attention to price and technological challenges affecting wheat farming as empirically revealed by this study. Nevertheless, diagnostic tests revealed that the model is the best fit for the specified structural equation as evidenced by its respective test statistics that were within the recommended thresholds (Table 12).

Table 11. Consequences of constraints on economic efficiency.

Variable (→)		Estimate (US)	Estimate (S)	SE	CR	P-value	R^2
F1	ME	-0.019	-0.037	0.006	-3.203	0.001***	-0.037
F3	ME	0.009	0.023	0.005	2.021	0.043**	0.023
F4	ME	0.016	0.049	0.004	4.100	***	0.049
F2	ME	-0.029	-0.042	0.008	-3.616	***	-0.042
ME	TE	1.000	4.606	-	-	-	4.606
ME	CE	-0.055	-0.097	0.478	0-.115	0.908^{NS}	-0.097
TE	CE	1.000	0.381	-	-	-	0.381
F1	C28	1.000	0.798	-	-	-	0.798
F1	C27	0.945	0.774	0.063	14.915	***	0.774
F1	C14	0.786	0.722	0.058	13.602	***	0.722
F1	C13	0.796	0.725	0.058	13.692	***	0.725
F1	C7	1.025	0.808	0.065	15.807	***	0.808
F1	C4	0.860	0.832	0.052	16.474	***	0.832
F1	C3	1.679	0.889	0.093	18.135	***	0.889
F1	C2	1.712	0.981	0.081	21.169	***	0.981
F1	C1	1.454	0.955	0.072	20.309	***	0.955
F2	C8	1.000	0.775	-	-	-	0.775

Table 11. Consequences of constraints on economic efficiency. (continued)

Variable (→)		Estimate (US)	Estimate (S)	SE	CR	P-value	R^2
F2	C9	1.019	0.743	0.075	13.508	***	0.743
F2	C11	0.999	0.698	0.080	12.541	***	0.698
F2	C22	1.184	0.740	0.088	13.455	***	0.740
F2	C23	1.721	0.937	0.094	18.237	***	0.937
F2	C24	1.702	0.927	0.095	17.966	***	0.927
F2	C25	1.164	0.862	0.071	16.318	***	0.862
F2	C26	1.211	0.875	0.073	16.629	***	0.875
F3	C20	1.000	0.919	-	-	-	0.919
F3	C18	1.015	0.913	0.040	25.614	***	0.913
F3	C16	0.924	0.888	0.039	23.810	***	0.888
F3	C10	0.800	0.843	0.038	20.942	***	0.843
F3	C6	0.985	0.833	0.048	20.375	***	0.833
F4	C21	1.000	0.988	-	-	-	0.988
F4	C17	0.718	0.725	0.064	11.306	***	0.725
F4	C15	0.341	0.314	0.066	5.167	***	0.314
F4	C5	0.648	0.565	0.071	9.066	***	0.565
CE	EFFP	-0.312	-0.568	0.012	-25.220	***	-0.568
TE	EFFP	1.000	0.695	-	-	-	0.695
Variance							
F1	-	0.518	-	0.064	8.061	***	-
F2	-	0.319	-	0.042	7.680	***	-
F3	-	0.879	-	0.088	10.025	***	-
F4	-	1.353	-	0.148	9.116	***	-
e27	-	0.144	-	1.249	0.115	0.908^{NS}	-
e30	-	-0.138	-	1.249	-0.110	0.912^{NS}	-
e29	-	0.056	-	0.006	9.230	***	-
e1	-	0.296	-	0.026	11.443	***	-
e2	-	0.309	-	0.027	11.506	***	-
e3	-	0.295	-	0.025	11.608	***	-
e4	-	0.295	-	0.025	11.602	***	-
e5	-	0.290	-	0.025	11.410	***	-
e6	-	0.170	-	0.015	11.315	***	-
e7	-	0.388	-	0.036	10.924	***	-
e8	-	0.060	-	0.011	5.483	***	-
e9	-	0.104	-	0.012	8.946	***	-
e10	-	0.212	-	0.019	11.135	***	-
e11	-	0.269	-	0.024	11.271	***	-
e12	-	0.335	-	0.029	11.408	***	-
e13	-	0.369	-	0.033	11.279	***	-
e14	-	0.132	-	0.016	8.259	***	-
e15	-	0.152	-	0.017	8.813	***	-
e16	-	0.149	-	0.014	10.435	***	-
e17	-	0.144	-	0.014	10.254	***	-
e18	-	0.162	-	0.019	8.316	***	-
e19	-	0.182	-	0.021	8.607	***	-
e20	-	0.201	-	0.021	9.444	***	-
e21	-	0.230	-	0.022	10.299	***	-
e22	-	0.377	-	0.036	10.425	***	-
e23	-	0.033	-	0.092	0.358	0.721^{NS}	-
e24	-	0.630	-	0.071	8.847	***	-
e25	-	1.438	-	0.122	11.805	***	-
e26	-	1.212	-	0.109	11.084	***	-
e28	-	0.002	-	0.000	11.874	***	-

***, **, * & ^{NS} mean significance at 1, 5, 10 % and non-significant respectively; US Unstandardized; S= Standardized; SE = Standard error: CR = Critical ratio; P = Probability; R^2 = Squared multiple correlation; → = relationship; and, e = error term.

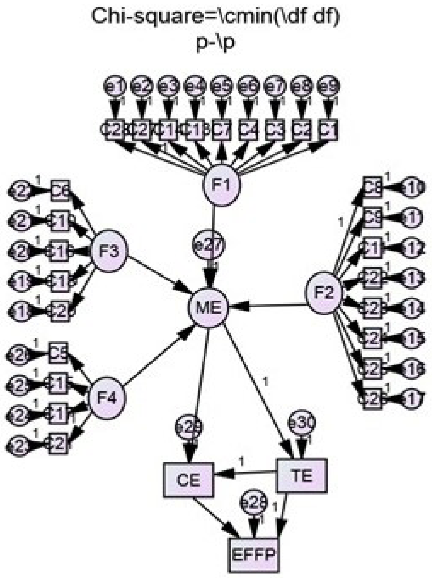

Figure 1. Structural modeling of the managerial efficiency [ME] on economic efficiency of wheat production.

Table 12. Model fit summary.

Category name	Index name	Obtained	Recommended
Absolute fit	CMIN	4324.888	-
	DF	373	-
	P	0.00	p<=0.05
	RMSEA	0.019	< 0.08
	RMR	0.013	<0.02
	GFI	0.945	> 0.90
Incremental fit	AGFI	0.953	> 0.90
	NFI	0.905	> 0.90
	RFI	0.97	> 0.90
	TLI	0.992	> 0.90
	CFI	0.925	> 0.90
	IFI	0.926	> 0.90
	PGFI	0.982	> 0.90
	FMIN	0.915	> 0.90
Parsimonious fit	CMIN/DF	1.595	< 5.0
Others	NPAR	62	-
	PRATIO	0.919	-
	PNFI	0.556	-
	PCFI	0.574	-
	NCP	3951.888	-
	AIC	4448.888	-
	BCC	4463.65	-
	BIC	4674.906	-
	CAIC	4736.906	-
	ECVI	15.776	-
	MECVI	15.829	-
	HOELTER (0.05)	28	-
	HOELTER (0.01)	29	-

It was established that the total effects of F1, F2, F3, and F4 on ME, TE (technical efficiency), CE, and EFFP were -0.019, -0.019, -0.018 and -0.014; -0.029, -0.029, -0.027 and -0.020; 0.009, 0.009, 0.009 and 0.007; and 0.016, 0.0016, 0.0015 and 0.0011, respectively. Besides, the total effects of ME on TE, CE, and EFFP were 1, 0.945, and 0.705 respectively, whereas the total effects of TE and CE on EFFP were 0.688 and -0.312 respectively (Table 13).

Table 13. Total, direct, and indirect effects of latent and mediating variables on the economic efficiency of wheat production.

Item	F4	F3	F2	F1	ME	TE	CE	F4	F3	F2	F1	ME	TE	CE
	Unstandardized							**Standardized**						
Total effect														
ME	.016	.009	-.029	-.019	.000	.000	.000	.049	.023	-.042	-.037	.000	.000	.000
TE	.016	.009	-.029	-.019	1.000	.000	.000	.227	.106	-.195	-.169	4.606	.000	.000
CE	.015	.009	-.027	-.018	.945	1.000	.000	.082	.038	-.070	-.061	1.659	.381	.000
EFFP	.011	.007	-.020	-.014	.705	.688	-.312	.111	.052	-.096	-.083	2.256	.478	-.568
Direct effect														
ME	.016	.009	-.029	-.019	.000	.000	.000	.049	.023	-.042	-.037	.000	.000	.000
TE	.000	.000	.000	.000	1.000	.000	.000	.000	.000	.000	.000	4.606	.000	.000
CE	.000	.000	.000	.000	-.055	1.000	.000	.000	.000	.000	.000	-.097	.381	.000
EFFP	.000	.000	.000	.000	.000	1.000	-.312	.000	.000	.000	.000	.000	.695	-.568
Indirect effect														
ME	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
TE	.016	.009	-.029	-.019	.000	.000	.000	.227	.106	-.195	-.169	.000	.000	.000
CE	.015	.009	-.027	-.018	1.000	.000	.000	.082	.038	-.070	-.061	1.756	.000	.000
EFFP	.011	.007	-.020	-.014	.705	-.312	.000	.111	.052	-.096	-.083	2.256	-.217	.000

Note: On request, the entire results can be produced.

4. Conclusions and Recommendations

Based on this study's findings, even though wheat production as an enterprise is profitable in the study area, farmers didn't achieve the target goals of output profit maximization and cost minimization. The inability of the farms to achieve these goals can be related to induced human risks such as poor labor productivity due to diminishing marginal returns associated with old age; gender discrimination that affected women's access to productive resources; ineffective advisory services delivery; capital consumption is triggered by enlarged income stream which inhibits re-investment; vulnerable large household size that drains business capital due to high expenditure on household's food and non-food items; poor prioritization of wheat farming as a business; and, challenges of land tenure system in the study area. Furthermore, evidence suggests that the enterprise is challenged with price/marketing, technological, managerial, and infrastructural risks, and these posed a threat to management efficiency which in turn affected cost efficiency, thus significantly plummeting the economic efficiency of wheat production in the study area. Therefore, for a long-run sustainable wheat production in the study area, we advise policymakers to pay more attention to price and technological challenges affecting wheat farming as empirically established by this study.

Contributor Roles

- Mohammed Sanusi Sadiq: conceptualization (lead), methodology (lead), validation, formal analysis (lead), investigation (lead), resources, data curation, visualization, supervision, writing - original draft (lead), writing- review & editing (lead).
- Muhammad Makarfi Ahmad: formal analysis, investigation, data curation (supporting), writing - original draft, writing- review & editing.

- Emmanuel Nkwi Gama: formal analysis, investigation, data curation (supporting), writing - original draft, writing- review & editing.
- Abbas Aliyu Sambo: formal analysis, investigation, data curation (supporting), writing - original draft, writing- review & editing.

Ethical implications

In accordance with the National Laws, ethics approval is not applicable. All participants in the survey have consented to their participation voluntarily.

Conflict of interest

The authors declare that they have no affiliation with any organization with a direct or indirect financial interest that could have appeared to influence the work reported.

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