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Do Small-Scale Wheat Farmers in China Struggle with Technical Inefficiency

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Abstract

Improving technical efficiency (TE) is crucial for the sustainable growth of smallholder agriculture in developing countries. Despite increased wheat output, the current supply is insufficient to meet growing demand, as wheat yields remain low regardless of more efficient farming practices. As a result, we designed this research to calculate and determine the causes of variation in the study area. A single-step stochastic frontier production model is used to analyze the information collected from respondents through in-person interviews. The average technical efficiency of wheat producers was found to be 90%, meaning they produced 10% less than their potential. The study also indicates that agricultural inputs, particularly fertilizers, and pesticides, significantly reduce wheat yield at 1% and 5% respectively. An increase in these inputs may lead to a decrease in wheat yield. However, at the 10% threshold, farm size significantly impacts yield. Socioeconomic factors such as level of education, farming experience, cost of seeds, and soil fertility have been identified as contributors to inefficiency in the research area. This study demonstrates that farmer inefficiency rather than random variance is the primary cause of the gap between actual and potential yields. Therefore, addressing issues impacting the technical efficiency of wheat producers in Qu Zhou County is the best option.

Keywords: Technical efficiency; Wheat producers; Stochastic frontier analysis; China

Introduction

In recent decades, there has been a significant agricultural output increase. However, the increase in observed output did not meet expectations, despite increased consumption of agricultural inputs. Increasing production and productivity among smallholder farmers is vital for agricultural development in developing countries (Ma et al., 2018; Qu et al., 2020). This can be accomplished by introducing modern technology or enhancing the efficiency of producers using a given level of input and technology (Wassie, 2014) [1].

Despite limited resources, China feeds a quarter of the world's population with only 7% of the arable land. Grain production has increased by over 50% in recent decades although excessive use of chemical substances has led to agricultural pollution, requiring urgent solutions (Carter, 2011). Since the Green Revolution, China has significantly increased grain production (Chen & Zhao, 2019). The use of new agricultural techniques has increased China's crop productivity, but challenges like drought and overuse of pesticides have prevented sustained yield increases (Hussin & Ching, 2013). Zhang et al. 2017 reported that smallholder farmers in China dominate agriculture and use 30% of the world's nitrogen fertilizers, leading to excessive usage in the region [2].

China's agriculture has improved due to increased inputs, technology, and institutional reforms, including the use of fertilizer and machinery (Feyisa et al., 2024). Farmers have adopted improved varieties and innovative models to increase agricultural technology adoption [3]. However, climate-related shocks have impacted the sector(Hussin & Ching, 2013) and Improper use of agricultural inputs, such as fertilizer, can harm the environment and hinder sustainable agricultural production(Ma et al., 2019), (Yin & Wu, 2021). Farmers may not be using modern agricultural technologies efficiently. According to Yao & Liu, (1998) improving technical efficiency is more effective than increasing inputs for maximizing agricultural production. Further output growth should rely on technical efficiency improvements. Therefore, studying technical efficiency is necessary to understand the technical efficiency of wheat producers in Qu Zhou County, estimate their level of technical efficiency, identify variations among farmers, and investigate yield gaps due to technical inefficiency [4].

Research Methodology

Method of data collection and sampling technique

The study used primary data collected from farm households in the North China Plain of Hebei province, Qu Zhou County, during the 2020 cropping season [5]. A structured questionnaire was prepared, and sample farmers were interviewed, considering a significant number of illiterate farm households. The study used both non-probability and probability sampling techniques within a general multi-stage sampling framework. Qu Zhou County was selected using purposive sampling based on the presence of science and technology backyards and the main crops cultivated in the area. Three villages were then purposively selected based on proximity and the crops produced, and 60 sample farmers were selected randomly and interviewed [6].

Method of data analysis

The data was analyzed using both descriptive and econometric tools. Descriptive methods involved using percentages, mean, standard deviation, and frequency analysis to examine the socioeconomic characteristics of wheat production among the sample farmers. Inferential statistics, such as t-tests and Chi-square (X^2) tests, were

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used to conduct statistical tests on continuous and categorical data, respectively. A single-step stochastic frontier model was employed to estimate the technical efficiency of wheat producers and then used a Cobb-Douglas production function for the study [7].

$$LnYi = \beta o \sum_{(n=1)}^{N} \beta n \; LnXni + \varepsilon_i \; (VI - Ui) \quad (1)$$

Where: ln represents the natural logarithm Y_i represents wheat output in kg; β vectors of the parameter to be estimated; Xi is the vector of inputs quantity expected to affect production function; εi is error term equals to (Vi - Ui); Vi represents the independently and identically distributed N (0, σ2) random error (statistical noise). The symmetric error term represents the deviation from the frontier due to factors beyond the farmer's control. It is randomly distributed in the production process and cannot be influenced by the farmer. The term Ui represents non-negative random variables associated with technical inefficiency in production, and is independently and identically distributed as half-normal with a mean of μ, where u~ (N+ (μ, σ2 u)). It measures the deviation from the maximum potential output due to technical inefficiencies in wheat production [8].

By using Equations 1[stated the maximum likelihood (ML) estimation of yield estimators for β and γ;

$$\sigma 2 = \sigma 2v + \sigma 2u \quad (2)$$

$$\gamma = \lambda 2 \; (1+ \lambda 2) \text{ or } \gamma = \sigma 2u/(\sigma 2v+ \sigma 2u) \quad (3)$$

The value of γ ranges from 0 to 1. If γ is 0, it means that the deviation of the firm's output from the frontier is entirely due to statistical noise. A γ value of 1 indicates that all differences occurred as a result of technical inefficiency. (Battese & Corm, 1977; COELLI, 1995). As stated by Aigner et al., (1977), the stochastic frontier production function technical efficiency of the ith farmer; en the level of inputs is defined as follows;

$$y_i/(f(x_i;\beta)\exp(v_i)) = \exp(-Ui) \quad (4)$$

Technical inefficiency effect is also expressed as follows

$$U_i = Z_i \delta + W \quad (5)$$

In this equation, Z_i is a vector of explanatory variables associated with the technical inefficiency effects, δ is a vector of unknown parameters to be estimated, and W_i represents unobservable random variables, which are assumed to be identically distributed [9]. These variables are obtained by truncation of the normal distribution with mean zero and unknown variance σ, ensuring that UI is non-negative. The term "TE" refers to the technical efficiency of the ith farmer. "Y" represents the observed output, and f (xi; β) denotes the deterministic part that is common to all producers, while exp(vi) captures the producer-specific part, which accounts for the effect of random noise on each producer. From equation (4), we can see that technical efficiency is the ratio of observed output to the maximum feasible output in an environment characterized by exp(vi). Furthermore, once the technical efficiency scores of the sample farmers were estimated, the potential output of wheat production in the study area was calculated using the following formula [10,11].

$$\text{Potential output} = (\text{Actual output})/(\text{Technical Efficiency}) \quad (6)$$

To assess the relationship between the variables in the model, a Multicollinearity test was conducted using the variance inflation factor (VIF). According to Akinwande et al. (2015), a VIF equal to 1 indicates Multicollinearity among variables, while a VIF greater than 1 suggests moderate correlation. A VIF between 5 and 10 indicates high correlation, which may pose problems [12]. If the VIF exceeds 10, it can be assumed that the regression coefficients are poorly estimated due to Multi collinearity. After determining the technical inefficiency of wheat producers within the sample households, the study aims to identify socioeconomic factors contributing to farmers' inefficiency. To do this, a generalized linear regression model was applied using ten inefficiency variables: household, education, family size, years of farming experience, farm size, credit access, extension services, distance from market, soil fertility, irrigation facility, and seed cost [13].

Results and Discussion

Demographic characteristics of sample households

The age of the household head is a key factor in determining a farmer's experience. The average age of the surveyed household heads is 56 years, with a standard deviation of 12 years. The youngest respondent is 30, and the oldest is 75. Education significantly improves farmers' knowledge and management skills, leading to higher agricultural output and productivity. The survey indicates that the average schooling for the sample farmers is 4 years, ranging from 0 years (illiterate) to a maximum of 9 years. The average farming experience of the sample wheat farmers is 34 years, with a range of 10 to 50 years. The survey also revealed that the average landholding of respondents in the survey area is 0.8 hectares, with a range of 0.13 to 2.33 hectares (Table 1) [14].

In this study, the majority of interviewed farmers were male-headed (83%), 94% were married, and 6% were widowed. Regarding education, 22.2% were illiterate, 75% attended primary school, and 2.8% attended secondary school (Table 2).

Table 3 shows dummy variables based on "yes" or "no" responses, concerning the soil fertility status of rural areas in wheat production. 97.3% of respondents reported having fertile wheat fields, while the rest reported barren fields. In this study area, formal credit services are unavailable, and farmers typically rely on informal sources for loans. The majority of wheat growers do not require credit services, as they can meet their own consumption and cash needs for the production cycle [15]. The survey found that 84.1% of sample producers did not receive loans from credit institutions, while 15.9% received loans from relatives and friends. Access to extension services, irrigation, and respondents who participated in off-farm activities for cash income is indicated (Table 3).

Table 1: Household characteristic variables.

Variables	Minimum	Maximum	Mean	Std. deviation
Age	30	75	56	12
Education level	0	9	4	2
Farming experience in years	10	50	34	12
The total area of land in ha	0.13	2.3	0.8	0.5
Source: own field survey 2020				

Table 2: Sex, marital status, and education status of sampled farmers.

Variables	Category	Percent (%)
Sex	Male	83.3
	Female	16.7
Marital status	Married	94
	Widowed	6
Education status	Illiterate	22.2
	Primary (1-8)	75
	Secondary (9-10)	2.8
Source: field survey, 2020		

Table 3: Descriptive summary of technical efficiency variables.

Dummy variables	Yes (%)	No (%)
Soil fertility status	2.7	97.3
Have access to credit	84.1	15.9
Have extension services	89	11
Have access to irrigation	0	100
Engaged in off-farm income	6	94
Source: own occupation 2020		

Table 4: descriptive statistics of both inputs and output variables.

Variable	Number 36	Mean	Std. Deviation
Output (kg)	60	8272	79
Area (ha)	60	0.81	0.51
Seed (kg)	60	224.7	53.5
Blended fertilizer (kg)	60	755	94
Herbicides L)	60	1.38	0.61
Insecticides(L)	60	0.97	0.4
Source: own occupation, 2020			

Descriptive results of wheat output and input variables used in the model

The production function's dependent variable is wheat output. The average wheat production per hectare is 8,272 kg, with a variation of 79 kg among growers. The average land area allocated for wheat production is 0.81 hectares, with variations of 0.51 hectares. Wheat growers use 224.74 kg of seed and 755 kg of fertilizer per hectare. Additionally, farmers employ mixed fertilizers and extensively use other agricultural chemicals such as pesticides and herbicides (Table 4) [16].

Result of econometric analysis

Parameter estimates of the SPF model

Before estimating SFM and farmers' technical efficiency, it's important to address multicollinearity among the variables in the model. The VIF test showed no evidence of multicollinearity issues among the variables.

In the study of wheat production, it was found that all inputs showed negative trends except for the land used for wheat cultivation. The amount of input factors, including the wheat cultivation area, fertilizer, and pesticide, significantly impacted wheat yield. The study recommends reducing fertilizer and pesticide use instead of increasing them, as their misuse can decrease wheat yield. This conclusion somewhat agreed with Rukwe & Zubairu, (2019) which found a negative effect of fertilizer and a positive effect of herbicide. However, it contradicted Mukete et al., (2016) which indicated that agrochemicals had a positive impact on yield in the case of Cameron. The results show that increasing the cultivated area of wheat production has a positive impact on wheat yield. Blended fertilizers have the highest influence on wheat production compared to other inputs. The estimated values of Sigma-u and Sigma-v indicate that the variation between observed and potential output is due to inefficiency (Table 5) [17].

Estimates of technical efficiency

The survey findings showed that the average technical efficiency of the sample farmers was assessed to be 90%, which indicates that farmers in the research region produced 10% less than their maximum output (frontier). A 10% loss of the wheat yield is caused by the farmers' inefficiency. According to this research, the wheat output may be improved while maintaining input levels if wheat farmers are more technically efficient. By using current inputs and technologies properly, farmers may raise output by 10% without using any extra resources. In the research region, the most productive farmer was able to produce 98% of what was possible, which was just 2% below potential output, while the least productive farmer was able to produce 79% of what was possible, which is 21% below frontier [18]. While the remaining percentage (i.e., 72.2) of wheat-growing farmers were able to create wheat yield over the mean efficiency level of sample farmers, around 27.8% of wheat-growing farmers were generating wheat yield below the mean technical efficiency level of farmers. (Table 6) [19].

Table 5: Maximum likelihood estimates of the cobb-Douglas SPF model.

Variable	Coefficient	Std. deviation
Constant	10.72	Omitted
Ln(area)	0.51*	0.03
Ln (blended fertilizer)	-.47***	0.09
Ln(seed)	-0.06	0.09
Ln(herbicide)	0.014	0.04
Ln(insecticide)	-.14 **	0.06
Sigma-u	.93 **	0.38
Sigma -v	. .09 ***	0.01
Lambda	9.83***	0.38
Log-likelihood function	-	31.3

Table 6: Frequency distribution of sample farmers' technical efficiency (N= 60).

Range of Technical efficiency	Observation	Percentages
<0.79	0	0
0.79 – 0.85	2	2.8
0.86 – 0.90	2	2.8
0.91 – 0.95	13	22.2
>0.96	43	72.2
Source: Own estimation, 2020		

Determinants of technical efficiency of wheat producers

The study found that education level has a significant negative impact on the technical inefficiency of wheat growers, suggesting that educated farmers are less inefficient compared to those without access to education. While contradicting Chigoma, 2015; Dhehibi et al., 2014) the results obtained by(Ateka et al., 2018; Mburu et al., 2014) accord with our findings. It has been discovered that supporting education is crucial to reducing wheat growers' technical inefficiency in the research region. Therefore, the responsible body should improve farmers' educational standing in all ways that enable them to increase their effectiveness. For instance, by offering training and knowledge in agriculture [20].

The farming experience of the sample farmers is a significant element that influences the technical efficacy of wheat producers. This variable's positive and substantial impact on wheat producers' technical efficiency at the 1% level of significance demonstrates that more experienced farmers are more technically proficient than less experienced ones. This may be the case because more seasoned farmers may be better able to gauge the complexity of wise farming decisions. In terms of resource allocation, they are also more technically effective. Our findings are supported by earlier research by(Fatima, 2016; Otitoju et al., 2018; Rukwe & Zubairu, 2019; Wake et al., 2019)

It was discovered that soil fertility status has a beneficial impact on wheat growers' technical efficacy. The outcome shows that the condition of the soil's fertility has a positive and significant impact on the technical effectiveness of wheat producers at the 1% level of significance, indicating that farmers who maintain their soil's fertility are more productive than those who maintain less of it. While (Tenaye, 2020) reported the same result as what we discovered,(Mamo et al., 2018) reported a different outcome. The price of seeds is also observed to increase farmers' inefficiency. With technical efficiency at a 10% level as per this study, seed cost is negatively significant. implies that since some farmers cannot afford it, the rising cost of seed reduces their ability to produce(Debebe et al., 2015). This result is consistent with the current investigation [21].

Potential Output and yield gap due to technical inefficiency

Since technical inefficiency was evident among wheat growers, it was determined that estimating the yield gap caused by inefficiency was a crucial issue. The difference between potential production and actual yield is used to calculate the yield gap caused by technological inefficiency on the part of farmers. Since the yield gap is a function of technical inefficiency, potential production is determined using the actual output and an estimated score of the technical efficiency of sample farmers. Although the measured yield was 8271.1 kg/ha, the study shows that technically effective ordinary farmers may generate 8615.6 kg/ha. The average yield difference in the research region, which was determined to be 344.5 kg/ha, suggests that work will be needed to narrow this gap [22,23].

Conclusion and Recommendation

Along with rice and corn, wheat is one of the major crops grown in China. Despite the farmers' adoption of better farming methods, the production was minimal and Wheat productivity was still less than frontier yield. Wheat production is influenced by both technical innovation and how effectively the already existing technologies are utilized. As for this study, socioeconomic, institutional, and environmental factors can impact levels of input consumption, and management practices. Wheat producers in the research region have varying levels of efficiency due to their inefficiency. According to the observed results, farmers in the study region have the option of either increasing input consumption by 4% without affecting current input levels or decreasing input consumption by 4% without affecting current wheat output. Farmers' technical inefficiency negatively impacted wheat output, indicating that there is a chance to boost wheat production by having wheat producers in the research region become more technically efficient. This study pinpointed elements that have an impact on policy and contribute to technological inefficiency.

Following the conclusion, significant policy suggestions were provided below. The government should advise farmers on how to use fertilizer, insecticides, and herbicides properly and monitor their application. Therefore, consistent and sustainable agricultural-related education should be provided by local government so that farmers can use the available inputs more effectively under the current technology. The result witnessed that education and technical efficiency have a positive correlation with wheat production. As a result, negative factors that follow the inappropriate use of these inputs could be minimized. Another element that adversely affects the technical inefficiency of wheat growers is the fertility of the soil. Farmers who can maintain their soil fertility are found to be more effective, and it is suggested that the local government give it the attention it deserves. Farmers should be encouraged to use soil fertility improvement approaches, cropping systems, and other related methods.

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