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Exploring the Relationship in Farmer Producer Organisation and Financial Assistance Programme (PMKISAN) in Measuring Technical Efficiency among Rice Farmers in India

Alok Kumar Pandey[1], Piyush Singh[1], Pawan Kumar Singh[2] and Annapurna Dixit[3]

ABSTRACT

The present study examined the impact of the two important initiatives for the farmers, the Farmer Producer Organisation and the Pradhan Mantri KISAN Scheme, on the technical efficiency of the rice growers in India. The stochastic frontier approach was applied to analyse 168 agricultural households producing rice in the Mirzapur District of Uttar Pradesh. These estimates found seed and irrigation as important variables influencing farmers' technical efficiency in this area. However, technical efficiency was recorded as relatively low, which justifies the possibility of improving the efficiency level through intervention. The mean technical efficiency was 84 per cent and 91 per cent for the two models, indicating that farmers with membership in the Farmer Producer Organisation and the financial assistance programme, as well as the PMKISAN schemes, benefit from these initiatives for efficient management, assistance, and utilisation of economic resources. The study recommends that the government and policymakers focus on establishing FPOs to improve access to resources, market networks, and bargaining power.

Keywords: Technical efficiency, stochastic frontier analysis, farmer producer organisation, PM-KISAN scheme, rice farmers

JEL codes: C51, D24, Q12, Q16, Q18

I

INTRODUCTION

Rice (Oryza sativa L.) is the world's most significant and widely produced food crop. Millions of people in Asian countries depend on it for up to 50 per cent of their daily caloric intake, as it is the primary crop farmed in developing nations (Awika, 2011; Muthayya et al., 2014). According to Valera et al. (2024), India is the largest producer of rice in Asia. With 44 million hectares under cultivation and a 40 per cent market share, India is the world's largest supplier of rice. The country's primary grain supply source, rice, is crucial for food security. The Food Security Act in India sponsored foodgrains by dint of the Targeted Public Distribution System TPDS (NFSA, 2013) to 75 per cent of the rural and 50 per cent of the urban population (Chakraborty and Sarmah, 2019). When compared to China, Vietnam, Thailand, and other Asian Countries, India's rice yield is still low (USDA, 2023). India faces significant challenges in feeding its growing population while possessing solid knowledge about rice agriculture. India's demand for rice is driven by both economic growth and population expansion (Samal et al., 2018). By 2050, the country is expected to need 137.3 million tons of rice domestically (CRRI 2013). In recent years, resource mismanagement, seed replacement, irrigation water

[1]Centre for Integrated Rural Development, Banaras Hindu University, Varanasi, [2]Lakshmibai College, University of Delhi, India, [3]Arya Mahila PG College, Banaras Hindu University

management, fertiliser, cropping pattern, crop residue, and knowledge about modern cultivation practices have been the leading causes of India's stagnation in rice productivity (Dis et al. 2015; UPSDR 2019; Nambiar and Abrol 1989; Ladha et al. 2009). According to the Central Rice Research Institute (2013), however, climate change and shifting agricultural land to other purposes would decrease the country's rice-cropped area by 6-7 million hectares by 2050. To enhance output and income in the agricultural sector, policymakers must have a thorough understanding of the technological efficiency of farmers (Fuwa et al., 2007). Farrell (1957) distinguished three categories of efficiency: allocative (price) efficiency, economic efficiency, and technical efficiency. Technical efficiency refers to the ability to produce a particular output level under a given technology with the fewest possible inputs (Aigner et al., 1977; Meeusen and van den Broeck, 1977; Khai and Yabe, 2011; Musaba, 2014). Production efficiency measurement techniques are divided into parametric and nonparametric categories (Farrell, 1957).

Aigner and Chu (1968) approximated the deterministic frontier production function using a Cobb-Douglas (CD) production function. Aigner and Chu (1968) employed the Cobb-Douglas (CD) production function to approximate the deterministic production frontier function. The method is unable to estimate model parameters and does not permit testing hypotheses regarding the model's fitness. Furthermore, it perceives all unknown changes (noise) as inefficiencies, leading to estimation errors, and it fails to establish a relationship between the inputs and outputs (Kiprono, 2013). Aigner et al. (1977) and Meeusen & Broeck (1977) extended the deterministic model to the stochastic production frontier to account for technical inefficiency, measurement errors, and statistical noise. It has been observed that random shocks, such as measurement errors, also affect the output level. According to Forsund et al. (1980), Battese (1992), Coelli et al. (1998), Dey (2000), and Dey et al. (2005), stochastic frontiers presume that the departures from the frontier are attributable to measurement errors and statistical noise and that others are attributable to firm-specific inefficiencies. Pitt and Lee (1981) and Kaliranjan (1981) were two of the first empirical publications to address the question of compensating for these inefficiency impacts. These pieces of work have a two-phase methodology. The stochastic frontier production functions are specified and estimated in the first phase. The technical inefficiency effects are predicted, assuming that the inefficiency is independent and has the same distribution. In the second phase, the inefficiency effects with identically distributed assumptions in the stochastic frontier are challenged with assumed technical inefficiency effects in the regression model.

Applying the stochastic frontier function, Kumbhakar et al. (1991), Ghosh, Reifschneider, and Stevenson (1991), and Huang and Liu (1994) developed the model to measure the effects of technical inefficiencies. Simultaneous estimation of the parameters is performed, assuming suitable distributional assumptions related to the cross-sectional data of the sample farms. These distributions include the production functions of the form quadratic, translog, transcendental, and Leontief, as well as the restrictive and simplest form of the CD production function (Abdulai and Huffman, 2000; Chirwa, 2007). For applications in the agricultural sector, the stochastic frontier technique was suggested (Coelli 1995a, b; Ferrara and Vidoli 2017). An added benefit of this method is that it may be used to evaluate theories regarding production structure parameters and the level of inefficiency. The analysis of technical efficiency provides important information on farmers and their capacity to increase the productivity of their farming operations and, consequently, competitiveness (Abdulai and Tietje, 2007). Many empirical studies, particularly those related to the development of agriculture, employ a Cobb-Douglas variant of SFA (Battese and Coelli, 1995). Numerous studies have estimated the level of technical efficiency over the past few decades, and a significant number of these have been conducted among rice farmers in India and other developing nations (Battese and Coelli, 1992; Wu, 1995; Latruffe et al., 2004). Technical efficiency has been estimated for Indian states like Assam (Bhattacharya 2016), Tamil Nadu (Kaliranjan 1981; Shanmugam and Palanisamy 1993; Tadesse and Krishnamoorthy 1997; and Mythili and Shanmugam, 2000), Uttar Pradesh (Datta and Joshi, 1992), Karnataka (Jayaram et al., 1987; Shanmugam, 2002), Bihar (Shanmugam 2000; Ahmad Nasim 2017) and Telangana (Nirmal et al. 2022; Samarpitha A 2017). Technical efficiency analysis of rice production in Bangladesh was conducted by Nargis et al. (2013), Hasnain et al. (2015), Majumdar et al. (2016), and Vortia et al. (2021). The technological efficiency of rice production in Vietnam was calculated by Khai and Yabe (2011), and in Myanmar, it was estimated by Tun and Kang (2015). Obianefo et al. (2021) found that lowland rice production has a greater technological efficiency than upland rice production in Nigeria. Additionally, Kadiri et al. (2014) found that household size and gender were determinants of technological efficiency in Nigeria's Niger Delta region.

Factors such as the current level of input amount, technology used, previous farming experience, landholding size, percentage of non-agricultural income, and level of education all affect farm efficiency (Souleymane, 2015; Lema et al., 2017; Wu, 2020; Unggul et al., 2015). Efficiency levels vary when using the different combinations of input and other factors. Kea et al. (2016) estimated that 34 per cent of the average technical efficiency has the potential to boost rice production by 66 per cent using existing technology and input levels. Wei (2020) estimated that the average farm-level technical efficiency is 80.49 per cent, meaning that rice production may rise by 19.51 per cent with the current input amount and technology. A study by Unggul et al. (2015) reveals that important drivers of technical efficiency include land size, age, wealth, and financing source. The average farm produced only 77 per cent of the maximum output that could be achieved at the input levels used.

The researchers reported that a variety of input resources, such as the amount of cultivated area, labour costs, seed costs, chemical and organic fertiliser quantities, pesticide usage, high-yield variety seeds, ploughing and mechanical labour costs, land rental expenses, farm size, irrigation costs, and capital representing the value of additional inputs and equipment, were being used inefficiently. The inefficiency variables that affect farming operations include land fragmentation, household size, education level, flood proneness, religion, access to government support, use of bullocks, size of the land holding, age of the household, family labor ratio in total labor used, training status, credit availability, distance, HYV adoption (percentage), gender, risk attitude, extension services, irrigation machine type, farming experience, subside, membership in a cooperative society, microcredit, and non-governmental organization services.

The Pradhan Mantri Kisan Samman Nidhi (PM-KISAN), a central sector scheme, was launched in 2019 to provide financial support to farmers. In the scheme, farmers receive Rs. 6000 annually, disbursed in three instalments of Rs. 2000. The payment is disbursed to beneficiaries' accounts using the Direct Benefit Transfer (DBT) system (PIB, 2023). 100467693 farmers benefited during the period Dec-March 2024-25 (https://pmkisan.gov.in/). The impact of PM-KISAN on farmers, as indicated by slight advancements in farmers' income, investment in agriculture, and the socioeconomic status of the household, has been found by many researchers (Varshney et al., 2020; Akhtar, 2022; Singh et al., 2025; Jagadeshwaran et al., 2024; Kumar and Burman, 2022). The benefits of the scheme to farmers have been observed in crops such as ragi in Karnataka (Kavitha et al., 2021) and millets in the state of Orissa (Kumar, 2023). On the other hand, no empirical study has been conducted on the influence of Pradhan Mantri Kisan Saman Nidhi (PMKISAN) and Farmer Producer Organisation (FPO) member farmers on the efficiency of rice production, nor on the input variable of insurance cost. The primary focus of the study will be to analyse the impact of these variables on the technical efficiency of rice production. This holds significance for advancing the agriculture sector and the general economic state. Thus, the primary objective of this study is to analyse one particular type of productive inefficiency, namely technical inefficiency, in rice production in Mirzapur District, Uttar Pradesh, India, and identify the factors that influence such inefficiency. From a policy perspective, this study is highly pertinent, as the majority of people in Mirzapur District rely on agriculture, specifically rice farming, as their primary source of income.

II

RESEARCH METHODOLOGY AND DATA

2.1 Research Region and Information Gathering

A field survey was conducted in the Mirzapur district of Uttar Pradesh in June and July 2023, as rice cultivation occurs during the kharif cropping season. The present study is based on primary data collected from 168 farmers spread across 20 villages in four blocks: Fatehpur, Nrayanpur, Rajghar, and Sikhan, in the Mirzapur

District, Uttar Pradesh. Forty-eight rice-producing farmers are members of a farmer producer organisation, while 120 farmers are not members of the farmer-producer organisation in the Mirzapur district of Uttar Pradesh. The PM-KISAN scheme has been operational since 2018. One hundred twenty-eight farmers benefited from the PMKISAN scheme among the survey families in the District. In this scheme, the government provides an annual income support of Rs. 6,000 (Rs. 2,000 in three equal instalments) to all land-holding farmer families. Personal interviews were conducted for this survey using a pretest-structured schedule as a guide. Data on output and farm inputs are gathered for the July-November 2022 farming season.

2.2 Data Overview

In the present study, rice production has been measured in terms of price. The entire area used to cultivate rice in bighas (1 bigha = 0.625 acres) was used to measure land in the eastern part of Uttar Pradesh, India. The cultivation cost, irrigation cost, total labour cost, and other inputs, such as fertiliser cost, pesticide cost, seeds, and herbicide, were measured in rupees (the Indian currency). Land rent and crop insurance costs for the rice crop were also estimated in rupees. In this paper, data on output and inputs are used to assess the technical efficiency of rice production at the farm level. The data characteristics, including mean, minimum, and maximum, are computed and presented in Table 1.

TABLE 1. DATA DESCRIPTION OF THE SAMPLE COLLECTED FROM THE STUDY AREA

Variables	Mean	Standard Error	Median	Minimum	Maximum
Output	144084	13340	93350	6000	1260000
Cultivation cost	12215	975	8100	700	78000
Seed cost	1133	83	800	100	6500
Irrigation cost	2433	426	0	0	38500
Fertilizer cost	9304	797	5670	405	72900
Pesticide cost	1835	271	800	0	27000
Herbicide cost	2198	198	1300	150	19200
Labour cost	24233	2430	14400	600	283500
Land cost	39892	3514	24000	2000	360000
Insurance cost	122	70	0	0	9900
Area under the crop	5.0	0.4	3.0	0.3	45.0
Farmers experience	26	1	27	2	60
Family size	4	0	4	1	8
Education	15	0	15	5	22
Agriculture Training (Dummy Variable)	-	-	-	0	1
Cooperative Member (Dummy Variable)	-	-	-	0	1
FPO Member (Dummy Variable)	-	-	-	0	1
PM KISAN (Dummy Variable)	-	-	-	0	1

Note: calculation based on the survey data conducted in June to August 2023.

The average farm size for the sample farmers in the study region is five bighas, with a minimum of 0.3 bighas and a maximum of 45 bighas. The average costs for the sample farmers' cultivation, seeds, irrigation, fertiliser, pesticide, herbicide, labour, land, insurance, and other expenses are Rs. 12215, Rs. 1133, Rs.

2433, Rs. 9304, Rs. 1835, Rs. 2198, Rs. 24233, Rs. 39892, Rs. 122 per bigha. This highlights the average investment required by farming households in the study area for successful farming and underscores the importance of efficient resource management for rice cultivation. Table 1 reveals that the average total value of rice output in the study region was Rupee 1,440.84, with a minimum of Rs. 6,000 and a maximum of Rs. 1,260,000. Furthermore, the farmers have been cultivating rice for about 26 years, on average, with experience. The formal education level of farmers is in the range of 5 to 22 years, with primary education accounting for five years, junior high school (JHS) for ten years, senior high school (SHS) for 12 years, graduation (UG) for 15, post-graduation (PG) for 17 years, and Doctor of Philosophy (Ph. D.) for 22 years. The average number of years of schooling (15 years) suggests that most farmers have finished their graduation education. Additionally, sample farmers had an average family size of four. Variables such as farmers who received any training related to agriculture, cooperative members, FPO members, and PMKISAN scheme beneficiaries were also used as dummy variables in the study to determine the effect on technical efficiency.

2.3 The understanding of technical efficiency

The measurement of production efficiency is divided into parametric and nonparametric categories (Farrell 1957). According to Aigner et al. (1977), the parametric technique is the stochastic frontier approach (SFA). Conversely, the nonparametric frontier makes no assumptions on the error term and does not presume any functional form. It utilises linear programming techniques. Data Envelopment Analysis (DEA) is the most popular nonparametric technique for measuring technical efficiency (Pradhan, 2018; Guha and Mandal, 2021; Hashmi et al., 2015; Abdulai et al., 2018; Abatania et al., 2012; Ahmad et al., 2012; Guzmán and Arcas, 2008). The disadvantage of the DEA is its inability to distinguish between inefficiency and statistical noise and/or measurement error (Abdulai et al., 2018). Technical efficiency (TE) can be defined as a firm's capacity to achieve a specific output level with a minimum number of inputs, given a particular technology, or as its feck to create the maximum amount of product with a given level of resources. Efficiency is the capacity to provide quality outcomes with minimal effort (Oyewo et al., 2008). The analysis of Technical Efficiency offers important information on farmers and their capacity to increase the productivity of their farming operations and, consequently, competitiveness (Abdulai & Tietje, 2007). Many empirical studies use a Cobb-Douglas, Constant Elasticity of Substitution, and translog production function variant of SFA, especially those that deal with developing agriculture (Battese and Coelli, 1995), (Chirwa, 2007). The error term is broken down into a one-sided efficiency component and a two-sided stochastic error, which represents the random influences outside the firm's control. According to Brettese (1992) and Coelli et al. (1998), stochastic frontiers postulate that some departures from the frontier are attributable to random events. Various functions can be used to estimate the physical relationship between inputs and outputs. Still, the Cobb-Douglas functional form is the most recommended option, mainly when the model includes three or more independent variables (Khai and Yabe, 2011; Bravo-Ureta and Pinheiro, 1997; and Ahmed et al., 2002). The Cobb-Douglas production function is unique and compelling because all input pairs must have a marginal rate of substitution that is independent of other inputs, and the elasticity of substitution must equal one. Stochastic noise and technical inefficiency may be separated from the divergence from the best practice frontier, which is the primary benefit of the stochastic frontier model. The data in developing nations are perforated with measurement errors and other stochastic factors. Thus, using the stochastic frontier model is the ideal choice for an accurate assessment (Fare et al., 1985; Kirkly et al., 1995, 1998; Jaforullah and Devlin, 1996; Coelli, 1998; Dey, 2000; Dey et al., 2005). Stochastic frontier techniques have been used in various recent studies to assess aquaculture efficiency in developing African and Asian countries (Gunaratne and Leung 1996, 1997; Jayaraman 1998; Sharma and Leung 1998, 2000a, 2000b; Sharma et al. 1999; Iinuma et al. 1999; Bimbao et al. 2000; Irz and McKenzie 2003; Chiang et al. 2004; Mohan et al. 2005; Singh et al. 2009; Alam et al. 2011; Kareem et al. 2008; Ekunwe and Emokaro 2009).

Technical efficiency or inefficiency determinants can be analysed using two different methods. Several researchers have employed the traditional method to examine the connection between efficiency and other socioeconomic factors (Kalirajan, 1981; Pitt & Lee, 1981). Initially, it calculates a stochastic production frontier, which is used for measuring technical efficiency at the farm level. The following important stage of the analysis involves estimating two limited Tobit equations for technical efficiency based on the characteristics of the farms and farmers in the study area (Lingard et al., 1983). The socioeconomic variables in the production frontier model estimation, suggested by economists (Kumbhakar et al., 1991; Reifschneider and Stevenson, 1991; Battese and Coelli, 1995), were included because they may have a direct impact on production efficiency in a comprehensive model. Kumbhakar et al. (1991) and Reifschneider and Stevenson (1991) proposed a single-stage stochastic frontier model. In this model, inefficiency effects are expressed as a vector of farm-specific variables and a random error component. The model effectively addresses the inconsistencies in the assumptions related to the independence of the inefficiency effects in the two-stage estimation procedure. The Battese and Coelli (1995) model is increasingly popular for estimating the impacts of technical inefficiency due to its ease of computation and capacity to perform econometrically consistent analyses of the effects of several farm-specific technical efficiency factors. Coelli (1996) developed the FRONTIER 4.1 software, which was used in papers (Battese et al., 1996; Wilson et al., 1998, 2001; Yao and Liu, 1998; Dey et al., 2000; Dey et al., 2005; Sharma and Leung, 2000a; Singh et al., 2009; Alam et al., 2011) to simultaneously estimate the parameters of the technical inefficiency model. Many research studies still employ the two-stage process despite the objections.

The stochastic frontier production function for the cross-sectional is as follows:

$$y_i = f(x_i;\ \beta)\exp\ (v_i - u_i)\ \ldots\ \text{(Equation 1)}$$

Where y_i represents the production of the i^{th} farm (i = 1, 2, 3, ..., n), x_i is a vector of known functions of production inputs and other variables (explanatory) related to the i^{th} farm, and β is a vector of length one by one measuring unknown parameters to be estimated. The v_i, random variable that are *i.i.d. (independently identically distributed)* N $(0,\sigma_v^2)$ and independent to the u_i's, while the $u_i's$ are non-negative random variables related to technical inefficiencies and independently distributed N $(Z_i\ \delta,\ \sigma_u^2)$. u_i's can be represented as follows, according to Battese and Coelli (1995):

$$u_i = Z_i\ \delta + W_i\ \ldots\ \text{(Equation 2)}$$

Where, Z_i is a 1 × p vector, δ is a p × 1 vector of parameters, and Wi's are the random variables with mean 0 and variance σ_u^2. The point of truncation is $-Z_i\delta$, that is, $W_i \geq Z_i\delta$ and u_i being N $(Z_i\delta,\ \sigma_u^2)$ distribution (Battese and Coelli, 1995).

The maximum Likelihood (ML) estimation approach is suggested for simultaneously estimating equations (1) and (2) for the parameters. The definition of the i^{th} farm's (TE) technical efficiency of production (Battese and Coelli 1992) is:

$$\text{TE} = \exp\ (-u_i) = \frac{Y_i}{f(X_i\ ;\ \beta)\ \exp\ (V_i)}\ \ldots\ \text{(Equation 3)}$$

Given the model assumptions, we predict the technical efficiencies using the conditional expectation in equation 3.

2.4 Empirical Model for Analysis

In the economics literature, two of the most widely used functional forms are the transcendental logarithmic (TL) and the Cobb-Douglas (CD). The CD production function offers a straightforward approach, but it has drawbacks in terms of technology, including a unit constant scale and output elasticity. A situation when the Null hypothesis: b_1+b_2+-------+b_{10}=1, where b is the elasticity of the input variable, but p-value < 0.05, which shows the null hypothesis is rejected, means the production function is not in the CD production function. In this situation, the alternative option is to select the translog production function. Yet the translog form of estimation is challenging due to the large number of parameters and multicollinearity issues among regressors. The translog model also offers a second-order approximation (Irz and McKenzie, 2003).

Following the logarithmic transformation to be calculated, the Cobb-Douglas stochastic frontier (SF) production function is expressed as follows:

$$\ln Y = b_0 + b_1 \ln X_1 + b_2 \ln X_2 + b_3 \ln X_3 + b_4 \ln X_4 + b_5 \ln X_5 + b_6 ln\, X_6 + b_7 lnX_7 + + b_8 lnX_8 + b_9 lnX_9 + b_{10} lnX_{10} + (Vi - Ui)\ \ldots\ldots\ldots \text{(Equation 4)}$$

Heteroscedasticity can be decreased by converting all stochastic frontier variables into natural logarithms. The variables are

Y_i = Rice output of the i^{th} farmer in quintal;

X_1= Cultivation price in Rupees of rice crop,

X_2 = Seed price in Rupees of rice crop;

X_3 = Irrigation price in Rupees;

X_4 = Chemical fertiliser price in Rupees;

X_5 = Pesticide price in Rupees;

X_6 = Herbicide price in Rupees;

X_7 = Rent of labour in paddy crop in Rupees;

X_8 = Land rent in terms of price in Rupees;

X_9 = Insurance cost of paddy crop in Rupees;

X_{10} = area under cultivated rice crop in bigha (Bigha is a land measurement unit in some regions of India; 1 Bigha = 0.625 Acres).

Equation 4 has been estimated using a one-step Maximum likelihood estimator for the CD stochastic frontier function and factors influencing technical efficiency. The intercept is represented by b_0, the maximum likelihood estimates (MLE) of the input variables are b_1, b_2,….,b_{10}, the estimated parameters are β, and the random variables that were previously described are V_i's and U_i's. The variance parameters,

$$\sigma^2 = \sigma_v^2 + \sigma_u^2 \text{ ; and}$$

$$\gamma = \frac{\sigma_u^2}{\sigma^2}.$$

Technical inefficiency distribution parameter, U_i is a function of certain farm-related and operational variables (Battese and Coelli, 1995). We are using seven related and operational variables, such as being a member of a farmer producer organisation, experience in agriculture, household size, educational level, training received, cooperative membership, and PM Kisan Samman Nidhi, which may affect the technical inefficiency of rice farmers. These variables are impacting technical inefficiencies. The study will also examine the influence of FPO membership and the PM Kisan Samman Nidhi scheme on technical inefficiencies. We employed three additional models to assess the impact of these exogenous variables individually or in combination. In Model 2, the PM Kisan Samman Nidhi variable was excluded. In Model 3, both the PM Kisan Samman Nidhi and FPO membership variables were omitted. Meanwhile, in Model 4, only the FPO membership variable was excluded, while the PM Kisan Samman Nidhi variable was retained. The technical inefficiency model (Model 1) is as follows:

$$U_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i} + W_i \quad \text{... (Equation 5)}$$

where

z_1 = Farmer producer organisation (if yes, the value is 1, otherwise 2)

z_2 = Experience (year)

z_3 = Household size

z_4 = Education level (year of schooling)

z_5 = Training received (1 for yes and 0 for no)

z_6 = Cooperative member (1 for yes and 0 for no)

z_7 = PM Kisan Samman Nidhi Received (dummy variable =1 for yes and 0 for no),

δ_0 Intercept & δ_1, $\delta_2 \cdots$, δ_7 are parameters to be estimated, and i = 1……n (Number of farmers).

Equation 5 provides that the technical inefficiency effects, or Ui's, are stochastic terms with specific distributional qualities (Coelli and Battese, 1996). We are using four different models to estimate the technical efficiency of the various farm-related and operational variables. The technical inefficiency model 2 without PM Kisan Samman Nidhi is as

$$U^1{}_i = \delta^1{}_0 + \delta^1{}_1 Z_{1i} + \delta^1{}_2 Z_{2i} + \delta^1{}_3 Z_{3i} + \delta^1{}_4 Z_{4i} + \delta^1{}_5 Z_{5i} + \delta^1{}_6 Z_{6i} + W^1{}_i \quad \text{…(Equation 6)}$$

where

z_1 = Farmer producer organisation (if yes, the value is 1, otherwise 2)

z_2 = Experience (year)

z_3 = Household size

z_4 = Education level (year of schooling)

z_5 = Training received (1 for yes and 0 for no)

z_6 = Cooperative member (1 for yes and 0 for no)

The technical inefficiency model 3 without the FPO member and the PM Kisan Samman Nidhi is as follows:

$$U^2{}_i = \delta^2{}_0 + \delta^2{}_2 Z_{2i} + \delta^2{}_3 Z_{3i} + \delta^2{}_4 Z_{4i} + \delta^2{}_5 Z_{5i} + \delta^2{}_6 Z_{6i} + W^2{}_i \quad \text{…(Equation 7)}$$

Where,

z_2 = Experience (year)

z_3 = Household size

z_4 = Education level (year of schooling)
z_5 = Training received (1 for yes and 0 for no)
z_6 = Cooperative member (1 for yes and 0 for no)

The technical inefficiency model 4 without the FPO member is as follows:

$U^3{}_i = \delta^3{}_0 + \delta^3{}_2 Z_{2i} + \delta^3{}_3 Z_{3i} + \delta^3{}_4 Z_{4i} + \delta^3{}_5 Z_{5i} + \delta^3{}_6 Z_{6i} + \delta^3{}_7 Z_{7i} + W^3{}_i$ …(Equation 8)

Where,

z_2 = Experience (year)
z_3 = Household size
z_4 = Education level (year of schooling)
z_5 = Training received (1 for yes and 0 for no)
z_6 = Cooperative member (1 for yes and 0 for no)
z_7 = PM Kisan Samman Nidhi Received (dummy variable =1 for yes and 0 for no),

Thus, it is interesting to test the null hypothesis that the technical inefficiency effects are non-stochastic, $\gamma = 0$, that is, that the technical inefficiency effects are absent,

$$\gamma = \delta_0 = \delta_1 = \ldots\ldots.. = \delta_7 = 0.$$

In that case, the stochastic frontier is a traditional average function, where the production function incorporates the explanatory variables from the model.

A stochastic frontier model is implied by

$$H_0: \gamma = 0.$$

Comparably, $\gamma = 1$ suggests that the technical efficiency accounts (Coelli, 1998) for all departures from the frontier.

The generalised likelihood ratio statistic, λ, can be utilised to evaluate these and similar null hypotheses. It is calculated as follows:

$$\lambda = -2[ln\{L(H_0)\} - ln\{L(H_1)\}] \quad \ldots\text{(Equation 9)}$$

Where the symbols $L(H_0)$ and $L(H_1)$ are likelihood functions of the null (H_0) and alternative (H_1), when $\gamma = 0$ is included in the hypothesis, then λ has a mixed $\chi 2$-distribution or an approximation $\chi 2$-distribution (if the null hypothesis is true) (Coelli 1995a, 1995b). The technical efficiency (TE) index for the i^{th} farm in the sample is as follows, given the model specifications:

$$TE_i = \exp(-U_i) \quad \ldots\text{(Equation 10)}$$

Technical efficiencies are predicted using the conditional expectation of equation 7 (assessed at the ML estimates) (Battese and Coelli 1995). The computer program FRONTIER 4.1 (Coelli, 1996) was used for estimation in the present study.

Table 2 displays generalised likelihood-ratio tests for all four models, which state that the inefficiency effects either don't exist or have simpler distributions.

TABLE 2. GENERALIZED LIKELIHOOD-RATIO TEST STATISTIC OF THE FOUR STOCHASTIC FRONTIER MODELS

Null hypothesis	Test statistic	Chi-square value	Decision
Model 1 (with all variables)			
$H_o: \gamma = \delta_0 = \delta_1 = \cdots = \delta_7 = 0$	24.73**	15.51	Reject
$H_o: \gamma = 0$	30.02**	14.85	Reject
$H_o: \delta_1 = \cdots = \delta_7 = 0$	17.15**	14.07	Reject
Model 2 (without PM Kisan Samman Nidhi)			
$H1_o: \gamma 1 = \delta_0^1 = \delta_1^1 = \cdots = \delta_6^1 = 0$	24.73**	15.51	Reject
$H1_o: \gamma 1 = 0$	-29.0927**	14.85	Reject
$H1_o: \delta_0^1 = \delta_1^1 = \cdots = \delta_6^1 = 0$	17.15**	14.07	Reject
Model 3 (without FPO member and PM Kisan Samman Nidhi)			
$H2_o: \gamma 2 = \delta_0^2 = \delta_2^2 = \cdots = \delta_6^2 = 0$	24.73**	15.51	Reject
$H2_o: \gamma 2 = 0$	15.13**	14.85	Reject
$H2_o: \delta_0^2 = \delta_2^2 = \cdots = \delta_6^2 = 0$	17.15**	14.07	Reject
Model 4 (without FPO member)			
$H4_o: \gamma 3 = \delta_0^3 = \delta_2^3 = \cdots = \delta_7^3 = 0$	24.73**	15.51	Reject
$H4_o: \gamma 3 = 0$	15.19**	14.85	Reject
$H4_o: \delta_0^3 = \delta_2^3 = \cdots = \delta_7^3 = 0$	17.15**	14.07	Reject

"**" indicates that the test statistic exceeds the value of the chi-square distribution at 5% level of significance

The models reject the first null hypothesis, which states that the inefficiency effects are not present. Additionally, there is a substantial rejection of the null hypothesis, stating that the inefficiency effects are not stochastic. Table 2 also presents the third null hypothesis, which states that the impacts of inefficiency do not follow a linear relationship with the characteristics of farmers' inefficiency. The likelihood ratio tests for the other three models also reject the null hypothesis.

III

FINDINGS AND DISCUSSION

3.1 Measuring the Technical Efficiency of Rice Farmers

It is clear from the results that cultivated areas under rice crops are significant and positive variables. This suggests that there may be a possibility of increasing the agricultural area to increase rice production. The positive and significant coefficients of seed show that there is scope for increasing rice productivity by using high-yielding seeds. A significant negative irrigation cost coefficient suggests that rice productivity would likely increase with a reduction in the number of irrigations. On the other hand, in all models, rice output is not significantly affected by the coefficients of cultivation price, fertiliser price, pesticide price, herbicide price, labour rent, land rent, and insurance cost since they are statistically insignificant. All models had positive and statistically significant coefficients for the area under rice crops. This suggests that expanding crop area may be a viable way to boost rice production. The area under rice crops has a coefficient of 0.95 in models 1 and 2 and 1.02 in models 3 and 4, meaning that a 1 Acre increase in the area of cultivation may result in a 95 per cent increase in output in models 1 and 2 and a 102 per cent increase in output in models 3 and 4. Some researchers supported the results of a study that found a positive relationship between farm size and efficiency (Carter, 1984; Pinherio, 1992; Curtis, 2000; Morrison, 2000; Latruffe et al., 2005; Kamruzzaman et al., 2006; Bozoğlu & Ceyhan, 2007; Sibiko et al., 2013; Pang et al., 2016; Abdallah et al., 2016; Tijani et al., 2006). However, other studies (Yotopoulos et al., 1971; Sidhu, 1974; Huang et al., 1984; Squires & Tabor, 1991; Reardon, 1997; Fletschner & Zepeda, 2002; Okoye et al., 2007) have found contradictory results. The coefficient of seeds is also determined to be 0.16 in models 1 and 2, and 0.10 in models 3 and 4, meaning that increasing the use of high-yielding seeds (which is more costly) might increase output in all four models, holding other factors constant. Similarly, in all four models, a one per cent increase in irrigation costs may result in a two per cent drop in output, according to the coefficient of irrigation cost, which is -0.02. The irrigation status of the farmers explains why farmers who own irrigation machinery are at least somewhat aware of the technical significance of farming, even though the majority of them frequently use expensive diesel pump sets for irrigation, which have a negative correlation with productivity. The findings of Kamal Jan et al. (2019) indicate that irrigation has a positive and significant impact on rice yield in Lower Dir, Pakistan; however, this does not align with the results of the present study. Numerous researchers have observed similar findings (Vangelis et al., 2001; Myint and Kyi, 2005; Shanmugam and Venkataramani, 2006), despite some studies (Bravo-Ureta and Evenson, 1994; Hallam and Machado, 1996; Amara et al., 1999) reporting contradicting results.

On the other hand, only one explanatory variable (FPO) of the inefficiency function is relevant in model 1. It implies that farmers who belong to FPO are less productive than those who do not. A larger family size appears to reduce inefficiency, as indicated by the farmers' negative and insignificant family size coefficient. For farmers with a significant pool of family members, using these labour resources during peak cultivation periods may be helpful. The PMKISAN scheme has a minor but positive effect on inefficiencies in rice production. The mean technical efficiency of rice producers in Model 1 is 84 per cent. This means that rice production may rise by 16 per cent with the current level of input and technology. The gamma (γ) variance ratio metric shows the one-sided error component accounts. The value of the ratio metric is 0.75, indicating that the one-sided error component accounts for 75 per cent of the total variance. Consequently, inefficiencies can be attributed to 75 per cent of the variation in data between farms, with pure noise contributing the remaining 25 per cent.

In the second model, we have dropped the dummy variable for the PM Kisan scheme (indicating whether the farmer received it or not). The results show that in Model 2, the FPO variable (dummy variable) in the inefficiency function is significant. The results show that farmers belonging to the FPO are less efficient than those who do not. The farmers' family size has a negative and insignificant coefficient, indicating that inefficiency decreases with increasing family size. The average technical efficiency of the rice producer in model 2 is 84 per cent.

Furthermore, in the third model, we have removed two dummy variables, FPO members and PM-KISAN Samman Nidhi, to verify that the model's inefficiency function exacerbates the inefficiency effect on rice output. The inefficiency function shows that a farmer's education has a dramatic impact on the inefficiency effect on rice output. The results align with the verdicts of Asante et al. (2014) and Donkoh et al. (2013). One theory suggests that educated farmers will likely have more employment options outside the farm, resulting in them investing less time and energy in their farming operations. Still, the result differs from our a priori estimate. Education is expected to improve the quality of work (Hyuha et al. 2007). Schultz (1975) asserted that education has a stronger effect in a rapidly evolving technological or economic context. Education has a positive impact on efficiency (Khan et al., 2010; Coelli and Battese, 1996; Battese et al., 1996; Seyoum et al., 1998).

The third model shows 91 per cent technical efficiency in the study area for rice growers without PM KISAN (dummy variable) and FPO members (dummy variable). The variance parameter γ has a strong positive association with rice production. It suggests that differences in farmers' technical efficiency levels explain around 95 per cent of the difference between the observed output and the output that can be produced at the maximum production frontier.

The fourth model estimates the technical efficiency by removing the FPO members (dummy variable). In this model, education had a significant and positive influence on the inefficiency of rice production. Results suggest that a higher degree of schooling decreased technical efficiency among rice farmers. The result validated the findings of Seyoum et al. (1998), who demonstrated that education has no significant effect on farmers' productivity using conventional methods. However, studies by Samarpitha et al. (2016) and Bhattacharyya and Mandal (2016) show that more educated farmers are typically more technically skilled. Research has demonstrated that acquiring agricultural knowledge through extended education can improve a farm's technical efficiency and learning capacity (Dhungana et al., 2004; Balcombe et al., 2008; Khan et al., 2010). The coefficient of the membership in the cooperative (dummy variable) is negative but insignificant. PMKISAN, initiated by the NDA government, marginally but favourably impacts rice production efficiency. In light of this, farmers who receive government support are more productive than the other farmers in our sample. The coefficient of the membership in the cooperative (dummy variable) is negative but insignificant. It has been observed that the farmer's household resources have a positive impact on rice yields (Lema et al., 2017; Unggul Heriqbaldi et al., 2015). Inefficiencies and potential improvements to agricultural productivity could be achieved with the support of inputs and policies related to farming. Most farmers in Uttar Pradesh are small-scale, marginal farmers who need more financial means to purchase the necessary inputs on time to maximise productivity. The negative coefficient for the family size shows that family members support farming by providing their services as farm labour. The gamma variance ratio metric (0.95) indicates that up to 95 per cent of the overall variance is attributed to the one-sided error component. Thus, inefficiencies can be responsible for 95 per cent of the variation in data between farms, with pure noise accounting for the remaining 5 per cent. The very significant value of σ^2 (0.19) indicates that technical inefficiency had a considerable role in the overall variability of rice crop production. The log-likelihood function's high and statistically significant value (102.48) suggests a good fit and the validity of the particular distribution assumption. The average technical efficiency score of the rice farms under examination is 91 per cent, indicating that rice fields in the study area could potentially increase their output by 9 per cent on average while maintaining the same input levels.

3.2 Scores for Technical Efficiency

The distribution of technical efficiency scores for models 1, 2, 3, and 4 is presented in Table 4. In models 1 and 2, and in models 3 and 4, the mean technical efficiency was determined to be 84 per cent and 91 per cent, respectively. The results suggest that rice producers, by and large, operate at an optimal efficiency level in their production process.

For rice producers, the overall technical inefficiency rates are 16 per cent for Model 1 (with PMKISAN and membership to FPO) and Model 2 (with membership to FPO), and 9 per cent for Model 3 (without PMKISAN and membership to FPO) and Model 4 (with PMKISAN), respectively. The results suggest that membership in the FPOs plays a crucial role in enhancing technical efficiency among rice-growing farmers by providing better access to resources, a market network, and bargaining power.

TABLE 3. MAXIMUM LIKELIHOOD ESTIMATES (MLE) OF THE STOCHASTIC FRONTIER MODELS OF THE RICE PRODUCER FARMER

Variables	Model 1		Model 2		Model 3		Model 4	
Stochastic Frontier	coefficient	t- ratio	coefficient	t-ratio	Coefficient	t-ratio	Coefficient	t-ratio
Intercept	10.583*	10.381	10.553*	10.502	10.998*	11.272	10.994*	11.584
Ln (Cultivation price)	-0.052	-1.027	-0.053	-1.050	-0.048	-0.995	-0.045	-0.933
Ln (Seed Price)	0.158*	4.507	0.158*	4.545	0.100*	2.803	0.098*	2.740
Ln (irrigation Price)	-0.024*	-6.583	-0.024*	-6.727	-0.023*	-7.181	-0.023*	-6.995
Ln (Fertiliser Price)	-0.008	-0.103	-0.008	-0.103	-0.018	-0.230	-0.013	-0.167
Ln (Pesticide Price)	0.002	0.451	0.002	0.438	0.000	0.106	0.000	0.065
Ln (Herbicide Price)	0.013	0.428	0.013	0.418	-0.022	-0.740	-0.022	-0.760
Ln (Labour Rent)	0.002	0.261	0.002	0.249	0.002	0.355	0.002	0.307
Ln (land Rent)	-0.065	-0.691	-0.060	-0.669	-0.054	-0.704	-0.059	-0.757
Ln (Insurance amount)	-0.009	-1.080	-0.008	-1.066	0.006	0.665	0.005	0.622
Ln (area under rice crops)	0.950*	7.890	0.947*	7.934	1.024*	8.626	1.023*	8.829
Inefficiency Function:								
Intercept	-0.561	-1.044	-0.570	-1.057	-5.098*	-5.211	-5.318*	-3.197
FPO member	0.215**	2.287	0.217**	2.298	-	-	-	-
Ln (Agriculture duration)	0.011	0.420	0.010	0.385	0.060	0.202	0.093	0.300
Ln (Family size)	-0.060	-0.938	-0.060	-0.945	-0.419	-0.435	-0.465	-0.592
Ln (Education)	0.148	1.162	0.149	1.154	1.537*	3.422	1.665*	2.952
Training status	0.032	0.317	0.033	0.315	0.268	0.274	0.313	0.331
Cooperative society	-0.002	-0.050	0.000	-0.010	-0.414	-0.689	-0.514	-0.742
PMKISAN	-0.008	-0.221	-	-	-	-	-0.252	-0.304
sigma-squared	0.022	2.863	0.022	2.882	0.180	1.248	0.185	1.300
gamma	0.748	5.457	0.750	5.228	0.945	19.513	0.947	21.000
Log likelihood function	109.21		109.19		102.28		102.48	
Mean TE efficiency	84%		84%		91%		91%	

Calculation based on survey data. Results are based on Frontier 4.1. *Significant at 1% level, ** significant at 5% level, *** significant at 10% level.

Every rice production model we tested for inefficiency complies with high efficiency. Only a few farmers in the study area operate at less than 60 per cent technical efficiency in any of the four models. In Model 1, 47 farmers operate rice farming on their farms with an efficiency of between 90 and 100 per cent, 64 farmers with an efficiency of between 80 and 90 per cent, and 48 farmers with an efficiency of between 70 and 80 per cent. In contrast, model 2 has 42 farmers who operate their rice farms at 90 to 100 per cent efficiency levels, 66 at 80 to 90 per cent efficiency levels, and 50 at 70 to 80 per cent efficiency levels. Model 4 suggests that direct financial support aiding in resource utilisation helps rice producer farmers enhance rice production. In contrast, model 2 has 66 farmers who operate their farms at efficiency levels between 81 and 90 per cent, 42 at levels between 91 and 100 per cent, and 50 at levels between 71 and 80 per cent. In model 3, 121 were between

TABLE 4. TECHNICAL EFFICIENCY SCORE IN FOUR DIFFERENT MODELS

Technical Efficiency interval	Model 1	Model 2	Model 3	Model 4
	Frequency (number of farms)			
40-50	1	1	1	1
50-60	1	1	1	1
60-70	7	8	1	1
70-80	48	50	7	7
80-90	64	66	37	35
90-100	47	42	121	123

Note: Calculation based on the survey data.

90 and 100 per cent efficiency level, 37 were between 80 and 90 per cent efficiency level, and seven were between 70 and 80 per cent efficiency level. Additionally, in model 4, 123 farmers operate their rice farms at an efficiency level of 90 to 100 per cent, 35 at an efficiency level of 80 to 90 per cent, and seven at an efficiency level of 70 to 80 per cent. The lower inefficiency rates suggest that targeted interventions can further enhance the technical efficiency of farmers involved in rice production. The frequency distribution of technical efficiency scores in rice production for the Mirzapur district is displayed in Figure 1.

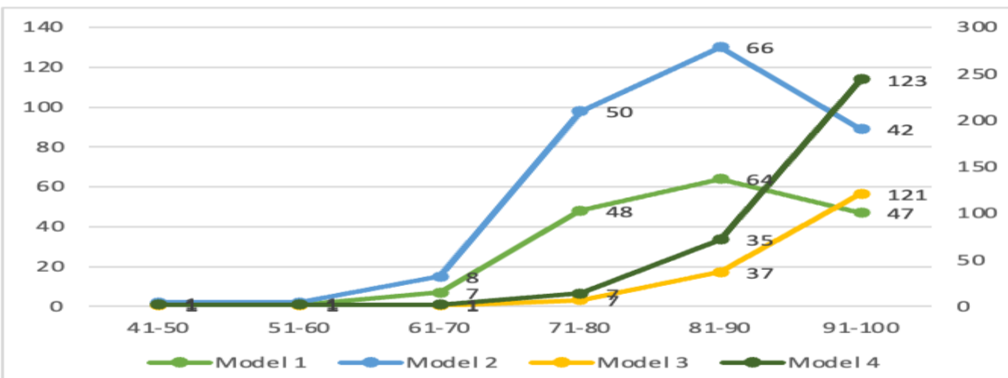

FIGURE 1. TECHNICAL EFFICIENCY FOR THE FOUR MODELS USED IN METHODOLOGY.

IV

CONCLUSIONS AND POLICY IMPLICATIONS

The paper aims to estimate the technical efficiency of rice producer farmers in the Mirzapur district of Uttar Pradesh, among members and non-members of the Farmer Producer Organisation, and among farmers who receive and do not receive the PM KISAN Samman Nidhi from the government of India. Primary data were collected using structured questionnaires from June to August 2023. The lack of empirical studies focusing on the efficiency of rice producers, particularly in light of the government's two key interventions, motivated the present study. The results of the maximum likelihood estimation suggest that the variables' seed' and 'area' have a significant positive impact, and irrigation has an adverse effect on Technical Efficiency. The majority of the farmers are operating at close to full-scale efficiency levels. The study suggests that targeted interventions, such as membership in FPOs and government financial assistance schemes, will reduce the technical inefficiencies of rice-growing farmers. The mean technical efficiency scores were 84 per cent and 91 per cent, respectively, according to the model used in the study. There is substantial potential in connecting farmers with the FPO, as well as providing more benefits under the PM-KISAN schemes for efficient management, assistance, and utilisation of financial resources. The study will provide policymakers with useful policy inputs for framing policies related to the rice crop.

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