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Economic analysis of inefficiency in wheat production: An empirical study from India

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ABSTRACT

The study undertook an effort to trace the production inefficiency between different farm sizes (i.e., marginal, small, semi-medium, and medium farms) for wheat crops in Uttar Pradesh, India. Using a sample of 320 farmers from the U.P., the study employed the stochastic production frontier (SPF) approach to determine the level of inefficiency using key inputs such as land, irrigation, fertilizer, seed, pesticides, equipment, and labour. Further, factors such as age, farm size (FS), soil fertility problem (SFP), awareness spearheaded by the panchayat (ASP), inaccessibility to certify seeds (ICS), and Simmons land fragmentation index (LFI) that accounted for inefficiency among various farm sizes have been taken into account. The study found that the inefficiency factors used in the study are hindering wheat production. The study exhibits significant differences among farm-wise inefficiency in Uttar Pradesh and therefore suggests the possibility of increasing the production of wheat crops in the state. The study recognizes that for farms with above-two-hectare land, production is relatively higher as compared to small and marginal farms' production. Thus, farms above 2 hectares are, in real terms, recognised as true economic holdings in the study, as they are less inefficient relative to others. The study suggests policy measures to improve the symmetrical information regarding input usages and interventions to reduce marginalisation in the state.

Contribution/ Originality: This empirical paper examines the farm-wise scale of inefficiency in Uttar Pradesh, India. This analytical work is different from other writings as it is centered to state where the most fragmented land is acclaimed with the highest share of marginal and small farmers. The study contributes to strategic agricultural planning that reduces the inefficiency in the production of wheat crops and empowers marginal and small farmers simultaneously.

1. INTRODUCTION

Wheat is one of the prime staple crops of India. It feeds approximately 80 million poor people who live below the poverty line in India (Saini & Gulati, 2016). It is one of the essential crops in terms of production and consumption. The production of wheat is mainly confined to the Region of Indo-Gangetic Plains and three northern states, namely Uttar Pradesh (35.53 percent), Punjab (18.96 percent), and Haryana (13.39 percent), respectively, and it accounts for around 72 percent of the total supply of India's wheat crop. Wheat production during the last decade has consistently risen from 86.87 million metric tonnes in 2010 to 107.59 million metric tonnes in 2019, although there was a downfall in 2012 and 2014. Despite this, the performance of wheat production at India's levels seems satisfactory. The story is somewhat different from the Uttar Pradesh point of view. In Uttar Pradesh, not only is the irregularity in wheat production evident, but the yield gap differentials also prevail among Western, Eastern, Central, and Bundelkhand regions (Dalwai, Raka, Suresh, Pawanexh, & Khan, 2019). Therefore, the present paper focuses on production irregularities as a challenge to identify the causes as a scope for further improvement in wheat production.

The agricultural sector in Uttar Pradesh plays an important role in the overall state economy through its significant contributions to rural employment, food security, and the provision of industrial raw materials to other sectors (Satyasai, Kumar, & Gupta, 2021). The agriculture sector provides direct livelihood to 59 percent of the workforce, while 77.7 percent of the state's population depends upon agriculture for their subsistence in Uttar Pradesh. Despite this, the performance in Gross State Value Added is not following the proportion engaged in agriculture, as a share of the primary sector is merely 25.2 percent in state GSVA for the year 2018-19 (George, 2018). Several factors have been blamed for the sluggish performance of the agricultural sector in Uttar Pradesh.

The recent release of land holding statistics in India reveals a noticeable drift among farm size composition, i.e., marginal holding has been persistently rising in India (Rajakumar, Mani, Shetty, & Parab, 2021). A continuous upsurge of marginal holdings depicts a diminution of land size that was not ideally efficient for agricultural purposes. The Uttar Pradesh farm size composition is not very far from all India land statistics. And thus, the outcome of the inefficiency in U.P. can be generalized to all India-level aggregates as far as land input is concerned. The process of marginalization is continuously intensifying in Uttar Pradesh as the marginal farms have increased from 76 percent in 2001 to 80 percent in 2015, while the area operated has marginally increased from 37 to 41 percent in 2001 and 2015, respectively (Dagar et al., 2021). Thus, the average size of land holding in the U.P. has reduced from 0.83 to 0.73 hectares in 2001 and 2015, respectively (Dagar et al., 2021). The continuous diminution of the land area not only restrains technological use but also increases land wastage, the most classic outlook known in agriculture (Kurukulasuriya & Rosenthal, 2013). Scholars have already established a relationship between farm size and agricultural productivity. However, one can see divergent views in support as well as in contradiction of the same (Chen, Huffman, & Rozelle, 2011; Gollin, 2019; Helfand & Taylor, 2021; Mahmood, Qasim, Khan, & Husnain, 2014; Omotilewa et al., 2021; Sheng & Chancellor, 2019; Wang, Chen, Das Gupta, & Huang, 2015). Therefore, it remains a debatable issue among scholars that still requires more insights. Especially for the state where the contribution of Uttar Pradesh state in the gross state domestic product (22 percent) is in the category of the top 6 states, but agricultural farm distribution is highly fragmented (Munnangi, Lohani, & Misra, 2020). Thus, the present paper took the former relationship as a base to evaluate whether the level of marginalization can be justified in the U.P. as a factor of efficiency or inefficiency. The objective of existing research paper is to identify inefficiency in wheat production within the given framework of socio-institutional structure in Uttar Pradesh and the determinants of such inefficiency. And to also evaluate whether these production inefficiencies are significant among different farm sizes or not. In other words, to find out whether the level of inefficiency among different farm sizes is in favour of the process of marginalization or not. A farm is technically efficient if the maximum output is obtained from the given set of inputs. Since farmers in agriculture have more command over the use of inputs, the input-oriented approach is being considered while performing the analysis. And any divergence from the minimum or optimal input use is considered inefficiency (Rahman, 2010; Tchale, 2009).

2. REVIEW OF LITERATURE

The association between arm size and productivity has been dealt with and distinctly contended in literature from time to time. Ghosh (1986) and Singh (2015) statistically validated that farm size and productivity have a positive relationship, particularly for the crop undergoing a technological transformation. Foster and Rosenzweig (2010) and Thapa and Gaiha (2011) also worked on the same line and exercised the plot-level panel data of the Rural Economic Development Survey from 1999 to 2008 and built a model. The model contains variables such as supervision costs, credit & risk imperfections, and economies of scale, and the result expounds that these variables account for inefficiency in small-scale agriculture in India. The authors further emphasized that, in comparison to medium- and large-sized landholders, a smaller percentage of smallholders operate in a lower range of yields. Wang et al. (2015) carried out a study on rice farm productivity in China and India. Findings revealed that agricultural yield increases with an increase in land holding size. In addition, Reddy (2015) scrutinized the state-wise drifts in the profitability of rice production. The results showed that profit creation was converging across all states, mostly due to the extensive use of inputs including farm machinery, fertilizers, and irrigation.

Farm size and productivity relationships are further studied in terms of the marginalization process of agricultural land, which implies a rapid increase in marginal land holdings with the passage of time (Scherr, 2000; Sklenicka, 2016). In the case of marginalization, several studies suggest that marginalization pushes land fragmentation and consequently affects the productive capacity of the land, thus stimulating land inequality too. It indicates the overutilization of natural resources, i.e., agricultural land (Sklenicka & Salek, 2008). A study conducted by Yadu (2015) emphasized the adverse impact of marginalization and traced that even after the much-touted agricultural land reform, marginalization land inequality in Kerala stood very high, thus triggering an overall social inequality. Few studies, such as those by Aryal, Maharjan, and Erenstein (2019); Bizikova et al. (2020); Choudhury and Sundriyal (2003); Gregory, Plahe, and Cockfield (2017) and Singh (2013), found that the marginalization process has increased the erosion of the real income generation capacity of the farmers and affected resource use efficiency. Gerber, Nkonya, and Braun (2014) and Tan, Chen, Xiao, Meng, and He (2021) exhibited that the marginalization process of agriculture land has gradually intensified poverty and land degradation.

Besides this, recent studies such as those executed by Mo, Hou, and Huo (2022) highlighted the degree of climate change and its impact on production efficiency, where climate change led to inefficiency in the production process. Further, state-wise agriculture production efficiency is analyzed in the Indian context by RL and Mishra (2022) who highlighted the negative impact of fragmented land holdings on agriculture production, while a few other studies in contradiction revealed that fragmentation of land holdings imposes a positive impact on agriculture production (Holzworth et al., 2015; Yu et al., 2022). Though this beneficial relationship might be temporary, the long-term impact of such a positive relationship between production and marginalized land might be detrimental to the outlook of land as an agricultural input. Another dimension of the inefficiency that influences production is the yield gap; thus, yield gap analysis is executed with the help of the production frontier technique (Meeusen & van den Broeck, 1977; Neumann, Verburg, Stehfest, & Müller, 2010). Clark and Tilman (2017) illustrated the impact of environmental factors on agriculture production, where the major inefficiency factor found was soil erosion, which led to the low fertility of the soil. In addition to this, in Ethiopia economic efficiency is significantly influenced by gender, age, education, and soil fertility. The policy measures suggested emphasize the expansion of education and soil conservation practices (Hörner & Wollni, 2021; Nigussie et al., 2017).

Therefore, it can be concluded on the basis of the above literature review that there is an unending debate going on about the relational function between farm size and agricultural production across the globe. However, the present study is focusing on U.P. in India, where some other variables, along with farm size, play a crucial role in determining agricultural inefficiency. These factors came into play due to the socio-institutional structure in Uttar Pradesh that holds a substantial place in Indian agriculture, i.e., the Panchayat System (Deshpande, Soni, & Shekhawat, 2013; Singh et al., 2019). Therefore, the present study endeavors to incorporate some additional inefficiency factors along with farm size, i.e., soil fertility problems, poor awareness spread by panchayats related to demonstration and usage of new technology, inaccessibility to certified or high-yield variety seeds, excess utilization of fertilizers, etc. Together, these sets of constraints lead to inefficiency in production, which in turn influences marginal and small farmers' profitability.

3. METHODOLOGY

The study was based on primary data gathered through the interviews in 2022-23. A total of 320 samples were collected using a multi-stage random sampling method. Utilizing this method, Uttar Pradesh State was categorized into four economic regions: Western, Eastern, Central, and Bundelkhand. And one district from each region has been selected as the primary sampling unit's (PSU's). Further, following the next stage, the random selection of the blocks was executed as secondary sampling units (SSU's), and finally, villages were selected as ultimate random sampling units (USU's). The villages that were selected under the multi-stage random sampling method can be seen in Figure 1. These 320 samples consist of 233 marginal farmers (< 1 hectare of agricultural land), 43 small farmers (1-2 hectares agricultural land), 24 semi-medium farmers (2-4 hectares of agricultural land), and 20 medium farmers (4-10 hectares of agricultural land).

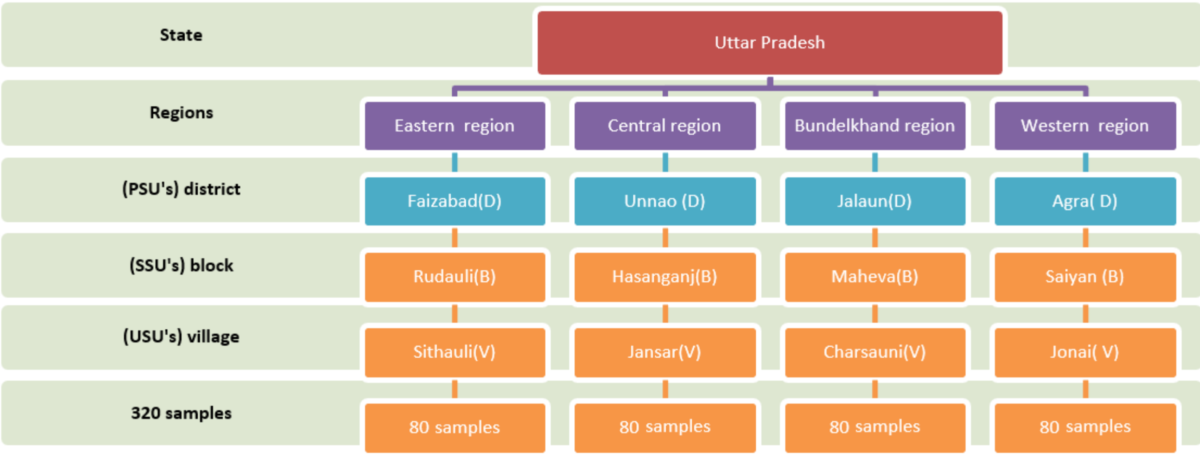

Figure 1. Sample selection structure.

3.1. Model and Measurement

The Stochastic production frontier is a premier approach to tracing technical efficiency or inefficiency.

Farrell (1957) having exercised the deterministic frontier production function, presented the work in a comparable manner. Every farm in the deterministic model has a production frontier, and any deviation from the frontier was understood to be the result of inefficiency. This method, however, ignored the reality that some elements, like weather, pests, and prices, are typically outside of a farm's control. Therefore, it gives genesis to the stochastic frontier model, constructed by Aigner, Lovell, and Schmidt (1977) which was a relatively more advanced method in the sphere of inefficiency analysis. The model uses a compound error term that consists of two parts: (i) an asymmetric component that allows for random fluctuations in the farms' frontier, or random shocks outside of the farm's control, and (ii) a one-sided component that represents the impact of technical inefficiencies. Additionally, because of the one-sided error component, the output function that is observed cannot be located above the border. Farm-specific efficiency and the random error effect may be distinguished, which is a benefit of the stochastic frontier over the deterministic frontier (Banik, 1994; Mythili & Shanmugam, 2000) and thus it is implemented in the existing study.

The present study measures the technical inefficiency of the individual farms and thus uses the stochastic frontier production function as discussed in Equation 1. The model typically states that agricultural output for the wheat crop is dependent on the expenditure on inputs such as land, irrigation, fertilizers, seeds, pesticides, equipment, and labour. However, the data is transformed to logarithm values before being taken into account for the final model.

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + (V_i - U_i) \quad (1)$$

Where:

Y = Output of wheat (Quintals)

X_1 = Land (ha) X_2 = Irrigation (Rupees)

X_3 = Fertilizers (Rupees) X_4 = Seeds (Rupees)

X_5 = Pesticides (Rupees) X_6 = Equipment utilized (Rupees)

X_7 = Self-owned labor (Rupees) β_0-β_7 = All Parameters to be estimated

In the above equation, ith farmer in the sample (i = 1, 2,..., N) was designated by the subscript "i"; *ln* stood for the natural logarithm, or the logarithm to base e); The investigation required an estimation of unknown parameters, which were the βs. Ui = One-sided inefficiency component; Vi = Random error, which has zero means and is related to random factors (e.g., measurement errors in production, weather, etc.) that were outside the farmer's control. Aigner et al. (1977) and Meeusen and van den Broeck (1977) separately proposed this kind of stochastic frontier where Vi, i = 1, 2,..., were considered to be independently and identically distributed.

Moreover, the factors responsible for inefficiency among different farms were taken into account to fulfill the objective of the study. Equation 2 exhibits that composite error as a parameter of inefficiency is an outcome of the age of the household, farmsize (FS), Soil Fertility Problem (SFP), Awareness Spread by the Panchayat (ASP), Inaccessibility to Certified Seeds (ICS), and *Simmons* Land Fragmentation Index (LFI). The inefficiency factors considered in the stochastic production frontier approach are described in Equation 2, given below:

$$\mu_i = \alpha_0 + \alpha_1(\text{Age}) + \alpha_2(\text{FS}) + \alpha_3(\text{SFP}) + \alpha_4(\text{ASP}) + \alpha_5(\text{ICS}) + \alpha_6(\text{LFI}) \quad (2)$$

Where α_0 is constant and α_1, α_2, α_3, α_4, α_5, and α_6 are the coefficients were unknown parameters to be estimated, together with the variance parameters, which were expressed in terms of Age, Farm Size (FS), and Soil Fertility Problem (SFP). The parameter λ explained the relative dominance of the inefficiency factor over a random error in the total composed error. Technical inefficiency of the i^{th} farmer in the appropriate data set for the individual farm was defined as $Technical\ Inefficiency = 1 - (\frac{Q_i}{Q_{i*}})$ where Qi* was the maximum possible output.

4. RESULTS AND DISCUSSION

To obtain the inefficiency in wheat production, information was collected on wheat production as the dependent variable and seven input categories, along with the six inefficiency effects that may explain inefficiency differentials among farm households. Table 1 exhibits the selected variables and their perspective units of measurement. Production is measured in quintals per hectare, and other independent variables are measured in rupees per hectare. Additionally, inefficiency factors such as age are measured in years, while the other factors are categorical in nature.

The descriptive values for the total sample size are described in Table 2. The estimated coefficients of the frontier production function in Equation 1 are given in Table 3. The study showed that all independent variables had positive coefficients except for irrigation and fertilizer. Land (0.77), Seeds (1.35), Pesticides (1.51), Equipment (0.75), and human labour (0.06) were positively significant, and that eventually indicates the scope for increasing production of wheat by increasing the expenditure on these inputs. This result is in accordance with Guteta and Abegaz (2016). While the coefficients for irrigation and fertilisers stood at -1.04 and -2.7, respectively, we found a significant reduction at the 1 percent level, which implies that a 10 percent reduction in the expenditure on irrigation will raise farm production by 10.4 percent.

Table 1. Variables for stochastic production frontier and technical inefficiency.

Variables		
A.	Production (Output)	Quintal per hectare
B.	Input categories	-
1.	Land	In Rupees per hectare
2.	Irrigation	In Rupees per hectare
3.	Fertilizers	In Rupees per hectare
4.	Seeds	In Rupees per hectare
5.	Pesticides	In Rupees per hectare
6.	Equipment	In Rupees per hectare
7.	Self-owned labour	In Rupees per hectare
Inefficiency factors		
i.	Age	In years
ii.	Farm size (FS)	Categorical
iii.	Soil fertility problem (SFP)	Categorical
iv.	Awareness spread by panchayat (ASP)	Categorical
v.	Inaccessibility to certified seeds (ICS)	Categorical
vi.	Land fragmentation index (LFI)	Absolute (0 to 1)

Table 2. Descriptive statistics of total sample farms.

Variables	Mean	Std. dev.	Min.	Max.
Total output	59	84	5	382
Land	1.23	1.79	0.09	9.75
Irrigation	7885	7203	806	32510
Fertilizer	6751	6059	743	31505
Seed	3035	3031	330	13493
Pesticide	1161	1126	140	5593
Equipment	5333	5536	535	32700
SOL wages	100582	33364	19000	203000
Inefficiency factors				
Age	50	12	22	75
FS	1.92	2.24	1	10
SFP	3.4	1.0	1	4
ASP	1.78	0.85	1	4
ICS	1.39	0.60	1	3
LFI	0.80	0.30	0.11	1

Note: 1. Primary Survey Data (2022-23).

Likewise, a reduction in the expenditure on fertiliser by 10 percent will raise farm production by 27 percent. The negative value of these coefficients in the model shows that the model allows for a reduction in the expenditure incurred upon irrigation and fertiliser to obtain the best-fit frontier for wheat production in Uttar Pradesh, India. It has been argued elsewhere that water utilisation in agriculture can be improved with more advanced and smart use of irrigation technologies on a large scale (Karagiannis, Tzouvelekas, & Xepapadeas, 2002). Further, the subsidised rate of fertilisers is the valid reason for incurring higher expenditure in the production process just with the motive to receive a high volume of crop (Akber, Paltasingh, & Mishra, 2022; Gupta, Tripathi, & Dholakia, 2020; Rakshit, 2018). Thus, with an increase in farm size, the model allows a reduction in over-expenditure due to the operation of economies of scale. The Gamma value is found to be 0.86, indicating the presence as well as the dominance of the inefficiency effect over random error in the model (Berger & Humphrey, 1991; Bidzakin, Fialor, & Asuming-Brempong, 2014; Klein, Herwartz, & Kneib, 2020).

Further, the significant and positive coefficient of land at the one percent level implied that by increasing 10 percent of the land (in hectares), wheat production increases by 7 percent, and this grasped inference was also previously recorded (Hussain et al., 2012; Yao & Liu, 1998). Similarly, the coefficient for the seed variable is observed to be significant at the 5 percent level, which indicates that a 10 percent increase in the expenditure of seeds and pesticides will raise the production by 13 and 15 percent, respectively. This likely datum was found by Ahmadzai (2017) and Wana and Lemessa (2019).

Table 3. Results of the stochastic frontier model.

Total production	Coefficient	Standard error	Z-value
Frontier			
Log (Land)	0.77***	0.06	12.09
Log (Irrigation)	-1.04***	0.23	-4.43
Log (Fertilizer)	-2.70***	0.28	-9.52
Log (Seed)	1.35**	0.42	3.15
Log (Pesticides)	1.51***	0.27	5.50
Log (Equipment)	0.75***	0.20	3.70
Log (Total wage SOL)	0.06*	0.03	2.09
Constant	8.63***	0.74	11.59
Mu			
Age	0.005	0.004	1.27
Farm size	-0.12*	0.06	-1.87
SFP	0.38*	0.17	2.15
ASP	-0.22**	0.08	-2.71

Total production	Coefficient	Standard error	Z-value
ICS	1.09***	0.24	4.46
LFI	1.79***	0.47	-3.78
Constant	-1.43	0.95	-1.50
U sigma	-2.24	0.27	-8.28
V sigma	-4.04	0.15	-26.7
Sigma u	0.32	0.04	7.37
Sigma v	0.13	0.01	13.21
Variance parameter(σ2)			
Gamma	0.86	0.57	21.42
Lambda	2.45	0.04	51.30

Note: 1. Primary Survey Data (2022-23).
2. ***, **and * Significant at 1,5 and 10 per cent level.

Moreover, the estimated coefficients for variables such as equipment and human labour have been found to be significant at the 5 and 10 percent level of significance, which indicate that an incline in the expenditure on equipment and human labour by 10 percent will augment wheat production by 7.5 percent and 0.06 percent, respectively. The low wage rate prevailing in the agriculture sector might be the reason that allows for incurring expenditure positively (Guo, Wen, & Zhu, 2015). There was sufficient scope for raising wheat production by increasing land area and expenditure on pesticides, seeds, equipment, and human labour. Perhaps the overall results revealed that inputs like land, seeds, pesticides, equipment, and human labour are underutilised to reach the best-fit production frontier. Besides, the coefficients of fertiliser and irrigation expenditure render it possible to raise production by reducing the expenditure on these inputs. However, it didn't imply an absolute reduction in the volume of irrigation. But the overall expenditure incurred on these two inputs needs to be reduced to reach the best-fit frontier. In the case of irrigation, there is ample scope to utilise advanced, efficacious irrigation methods. This phenomenon of incurring more expenditure is observed in the study because marginal farmers usually prefer the customary hiring for irrigation as they don't have their own source of irrigation; on the contrary, semi-medium and medium farmers have their own source of irrigation (Aryal et al., 2019). However, in the case of fertiliser input usage, farmers have the misconception that the "*higher the use of fertiliser, the higher will be the production*" (Chand, Prasanna, & Singh, 2011; Wu et al., 2018). This misconception pushed farmers to escalate the consumption of fertiliser in growing wheat crops, which was causing a rise in expenditure on the particular input.

However, the main cause of technical inefficiency was the small farm size, as the majority of the land is gradually moving towards diminution and increasing fragmentation, and other factors such as the Soil Fertility Problem (SFP) and Inaccessibility to Certify Seeds (ICS), Awareness Spread by Panchayat (ASP) for technology demonstrations were accountable for increasing technical inefficiency in the production of wheat crops. Hence, the application of the Stochastic Production frontier model revealed that an increase in the number of marginal & small farms was bringing down agricultural production, and consequently, it influenced the income-generating capacity of the farmers too. This was a key concern for marginal and small farmers. Similarly, the Land Fragmentation Index (LFI) and technical inefficiency expounded the direct relation in the model. If the land fragmentation deepens further, inefficiency in wheat production will also increase. Hence, the continuous increase in diminutive land adversely impacts wheat production and was traced as an inferential fact in the study. Moreover, Reddy and Sen (2004) flaunted that technical inefficiency in rice production decreases with the increase in farm size in Bihar state. A similar notion was found in Central Ethiopia by Bekele, Viljoen, Ayele, and Ali (2009) and the study revealed that an increase in farm size is likely to reduce inefficiency in the production process of wheat crops.

Likewise, Dessale (2019) and Zhong, Zhu, Chen, Liu, and Cai (2019) divulged that in countries like China and Ethiopia, as the farm size improved, there was an effective scope to reduce inefficiency. Further in the same line, technical inefficiency and farm size were traced to be negatively associated in the comparative study of Uttar Pradesh and Punjab state of India (Shekhar, 2022). In the same line, Pradhan and Mukherjee (2018) discovered that farmers' education, agricultural production process, proportion of irrigated area covered by canals, yielding a variety of lands, government services, and agricultural expenditure by local government significantly contribute to efficiency in resource utilization in farm production.

Table 4. Frequency distribution of technical inefficiency of selected farms.

Technical inefficiency	Marginal	Small	Semi-medium	Medium	Total
0-10	71 (73.9) [30.47]	0 (0) [0]	13 (13.5) [54.1]	12 (12.5) [60]	96 (100) [30]
10-20	119 (88.8) [51.1]	1 (0.75) [2.33]	6 (4.48) [25]	8 (5.97) [40]	134 (100) [41]
20-30	21 (100) [9.1]	0 (0) [0]	0 (0) [0]	0 (0) [0]	21 (100) [6.56]
30-40	7 (58.3) [3]	1 (8.33) [2.33]	4 (33.3) [16.6]	0 (0) [0]	12 (100) [3.7]
40-50	2 (50) [0.86]	1 (25) [2.33]	1 (25) [4.17]	0 (0) [0]	4 (100) [1.25]
50-60	5 (55.56) [2.15]	4 (44.4) [9.30]	0 (0) [0]	0 (0) [0]	9 (100) [2.8]
60-70	4 (36.36) [1.72]	7 (63.64) [16.28]	0 (0) [0]	0 (0) [0]	11 (100) [3.44]
70-80	4 (21.05) [1.72]	15 (78.9) [34.8]	0 (0) [0]	0 (0) [0]	19 (100) [5.9]
80-90	0 (0) [0]	13 (100) [30.2]	0 (0) [0]	0 (0) [0]	13 (100) [4.6]
90-100	0 (0) [0]	1 (100) [2.33]	0 (0) [0]	0 (0) [0]	1 (100) [0.31]
Total	233 (72.8) [100]	43 (13.4) [100]	24 (7.5) [100]	20 (6.25) [100]	320 (100) [100]

Note: 1. ( ) shows row wise percentage.
2. [ ] shows column wise percentage.
3. Estimated from Table 3

Table 5. Farm wise differences in technical inefficiency of farms (ANOVA statistics).

Farm category	Mean	Standard deviation	Frequency
Marginal farms	21.4	14	233
Small farms	76.9	15.2	43
Semi medium farms	19.1	12.8	24
Medium farms	14	5.02	20
Total	28.2	23.6	320
Source	SS	DOF	MS
Between group	118881	3	39626.8
Within group	59674.1	316	188.8
Total	178555	319	559.7
F-value	209.8	Prob>F	0.00

Note: *Bartlett's test for equal variance: Chi2 (3) = 22.79 Prob>Chi2=0.000.
Significance at a 1% level of significance implies differences in the technical inefficiency among the four farm groups.
SS-Sum of squared deviation.
DOF-Degree of freedom.
MS- Mean square deviation.

Table 4 was imperative to understand the range or scale of inefficiency among the farms. It depicted the farm-wise distribution of technical inefficiency in wheat production. The table gives the absolute frequency and percentage of the computed inefficiency within the particular farm and across the different farms. The table revealed that marginal and small farms were relatively more inefficient as compared to semi-medium and medium farms. Inefficiency ranges from 0 percent to 80 percent for marginal farms, while for small farms, inefficiency extends further and lies between the ranges of 10 percent and 90 percent. Moreover, in the case of semi-medium farms, it ranged from 0 percent to 50 percent, and lastly, for medium farms, inefficiency ranged from 0 percent to 20 percent only.

Furthermore, a close study of the detailed distribution of inefficiency across the different farm sizes showed that between 0 and 10 percent, marginal farms have the most inefficiency (73%), followed by semi-medium farms with 13% and medium farms with 12.5%. Similar to this, the 10 to 20 percent range of inefficiency consists of 88.8 percent inefficiency for marginal farms, 5.97 percent inefficiency for medium farms, and 4.48 percent inefficiency for semi-medium farms. Moreover, the 20–30 percent range of inefficiency showed that no farm is inefficient between these ranges except marginal farms. Similar to this, the inefficiency is between 30 and 40 percent, with marginal farms having a 58 percent inefficiency rate, semi-medium farms having a 33.3 percent inefficiency rate, and small farms having an 8.3 percent inefficiency rate. Similarly, the inefficiency ranged between 40 and 50 percent for marginal farms, followed by 25 percent for small and semi-medium farms. The inefficiency ranged between 50 and 60 percent, comprising 55.5 percent inefficiency for marginal farms and 44.5 percent inefficiency for small farms. Further, the inefficiency range between 60 and 70 percent contains 63.6 percent inefficiency for small farms and 36.4 percent inefficiency for marginal farms. As we further move to the higher range of inefficiency of 70–80 percent, only marginal and small farms were found to be inefficient. Lastly, the inefficiency range of 80–90 percent comprises the inefficiency for small farms. Hence, it was clear from the table that a high range of inefficiency was detected for the marginal and small farms as compared to the semi-medium and medium farms. Thus, it was verified that there was no equal level of technical inefficiency among the different categories of farms. Further, the significance of the different levels of technical inefficiency was additionally statistically tested with the help of an ANOVA in Table 5.

Table 5 shows the ANOVA results that show differences in technical inefficiency by farm size between the marginal, small, semi-medium, and medium farm groups. The level of inefficiency in one farm category was different from another, which was analyzed with the help of the ANOVA test. The null hypothesis of the ANOVA states that technical inefficiency was at the same level among the different farm sizes. The test verified that inefficiency among the four types of farms was unevenly distributed. The score value of the ANOVA was found to be statistically significant. Therefore, the null hypothesis was rejected as per the results. The perusal of Table 5 revealed that the mean inefficiency for small and marginal farms was higher than for semi-medium and medium farms. Therefore, special and effective inefficiency preventive steps are required for marginal and small farms in the Uttar Pradesh so that efficiency in wheat production can be increased.

5. LIMITATION

The present study came out with pertinent findings, but a few limitations were met in the process of completion. The study mainly covers the wheat crop for frontier analysis; however, wheat is not the only crop produced in the state. Thus, to measure the inefficiency of the whole agricultural sector in the U.P., more crops can be incorporated into the study by the scholars in the future. Further, the study prioritised Uttar Pradesh state over India to conduct the primary survey for frontier analysis, as the highest marginalisation could be seen only in this state in India. Further, due to time and financial constraints, other states couldn't be included in the sample size, which may increase the complexity. Therefore, the present study is confined only to the Uttar Pradesh state of India.

Additionally, future research can incorporate climate change, arable land, grassland, etc. as a factor in inefficiency into the study, as this would change the dynamics of agricultural production worldwide.

6. CONCLUSION

The study concluded that there was significant variation in the technical inefficiency scores for the different farm sizes. To be specific, the mean value for inefficiency is highest for small farm sizes, followed by marginal, semi-medium, and medium farm sizes. Further, this inefficiency can be reduced in wheat production by improving the farm size, spreading awareness by Panchayat on technology demonstrations, providing proper accessibility to certified seeds, and reducing soil fertility problems. Further, it can be deduced from the study that the technical inefficiency among marginal and small farms may de-escalate if the proper action plan to improve farm size, soil fertility, and utilisation of certified seeds is followed and implemented. Besides, the most pertinent and crucial factor that can improve the technical efficiency in the production of the wheat crop is the awareness spread by the Panchayat on technology demonstration, and it plays an extremely significant role in guiding and directing the farmers to increase production efficiency. Further, marginal and small farms were found to be less technically efficient, and the major cause behind this was constraints put on land size, i.e., the size of less than 2-hectare land. Thus, the study recognised that economies of scale are more enjoyed by landholdings whose size is above 2 hectares, and therefore they are recognised as true economic holdings. The policy implication of the study suggests working in the direction of disseminating the information symmetrically, either through the active participation of Panchayat representatives or via some other substitute mechanism by the state government. Further, the study revealed that the ongoing marginalisation process is not good as it delimits the production potential of this very sector. Therefore, this area also needs policy intervention, either to slow down existing marginalisation or minimise it in the U.P. as well as at the Indian level.

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