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# Impact of Agriculture Technology Adoption on Productivity and Efficiency: Primary Panel Data Analysis

***ABSTRACT***

Agricultural technologies have been promoted by the government to increase productivity and efficiency. However, adoption of new technology is very low because of lack of knowledge and awareness. The study estimates the impact of agriculture technology adoption on productivity and efficiency. The current study uses primary panel data of base year (2006-07) and end year (2018-19). Further, it has also explored the socioeconomic indicators responsible for productivity and efficiency in the area. A propensity score matching approach has been used to identify the factors responsible for productivity and efficiency. The ordinary least square (OLS) and frontier production functions are used to estimate parameters of agriculture technologies. The seven technologies have significant impact on various levels and positively affect productivity in the area. The positive factors influencing efficiency are farmers age, education of farmer and farmer operational area while during 2018-19, the factors increase technical efficiency are family size, household family member employment, livestock ownership and operational area respectively. The study recommends some policy implementation that improves the technological adoption to increase productivity and efficiency in the region.

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# 1. INTRODUCTION

Agriculture sector growth is an important sector in fostering economic development and feeding the growing population specific to developing countries. The previous studies show that area expansion and irrigation have already become a minimal source of output growth at a world level. The agriculture sector's growth depends on new and improved technologies adoption. Empirical findings indicate that the advantages of modern agricultural technology benefit the poor both directly by increasing farm households' earnings and indirectly through expanding employment options with rising wages (Nguezet et al., 2011).

Productivity is the combination of output to input (ratio of output to input). At its most central level, productivity measures the amount produced by a target group at a given set of resources and inputs. Productivity may be measured as a single entity or group of farms at any geographical location. Micro-based actions are required for the comparison of productivity between farms. Productivity is taken as a measure of performance. It is defined as the ratio of outputs to inputs. The ratio shows the performance level. Productivity is considered an economic concept because it measures the amount of output produced from available resources. It also indicates a good measure of sustainability over time (OECD, 2001).

In keeping with international initiatives like the 2030 agenda for sustainable development, several nations have implemented programmes to increase agricultural output. Where this sector is a significant economic sector, the agriculture sector is of highest concern. Because it successfully reduces poverty through improved food security and higher farmer income, increasing agriculture production is crucial. According to empirical studies, this will eradicate hunger. In order to embrace and enhance production techniques and technologies, productivity can be increased. Agriculture productivity measurement dates back to the traditional theory of economic growth and is not a recent development. Various scholars' most significant contribution is to improve our understanding, measurement, and analysis of agricultural productivity (Solow, 1957).

Most developing nations must make increasing overall production and productivity a top priority in their policies; it is not a choice. It is possible to increase output and productivity in two different ways. The first is accomplished by improved input utilization and/or technology advance at the level of input. Enhancing the effectiveness of producers or businesses that have shown a fixed level of inputs and technologies is the second strategy to increase productivity. Research on efficiency assessment is still important, especially in developing nations where resources are limited and possibilities to advance their economies by creating or using superior technologies are disappearing. The most common economics concept is efficiency (Tadesse et al., 1997).

The current study’s primary objective is to assess how adopting new agricultural technologies affects production and efficiency. Adoption of agricultural technology is essential for increasing production and efficiency. In order to determine how these technologies, contribute to productivity and what factors affect efficiency levels in the Faisalabad district, Punjab (Pakistan) by using seven technologies. The objective of the current study is the evaluation of agricultural technologies and associated factors. It also explores the factors responsible for boosting technological efficiency.

The main objectives of this study are:

- To examine the role of agriculture technology adoption on productivity and efficiency in the area for both periods (2006-07, 2018-19).
- To explore socioeconomic and other factors responsible for technical efficiency in the area for both periods (2006-07, 2018-19) and to assess the change during the study period.

Based upon the study's research as mentioned above questions and objectives, the following hypotheses are formulated for the present essay.

- $H_1$: Agriculture Technologies Adoption is responsible for agriculture productivity in the district Faisalabad, Punjab, Pakistan.
- $H_2$: Agriculture Technologies Adoption has the same impact for both periods; base period 2006-07 and end period 2018-19.
- $H_3$: The socioeconomic, demographic, and assets variables are influencing factors of technical efficiency in the Faisalabad district, Punjab (Pakistan)

The empirical studies conducted in developed and developing countries to investigate the factors responsible for productivity and efficiency. The previous studies used production, cost, etc., functions to determine factors responsible for productivity and identify efficiency factors. A few or no studies were conducted to assess the impact of technological adoption on productivity by using panel primary data. The current study fills this gap by using seven various technologies' adoption roles in productivity, and further investigated factors accountable for efficiency in the area.

Additionally, the previous studies used cross-sectional data for one year or secondary data to assess the productivity and efficiency factors. But the current study identifies the technology adoption role in productivity and efficiency factors by using micro panel data collected from field surveys (farmer interviews) from the district for two time periods (2006-07 base period & 2018-19 end line period). A separate analysis has been done for a comparative analysis of both periods.

So, the current study has an outstanding contribution to literature and future policy option to assess the technology adoption role in productivity and efficiency. The study opens a new horizon to evaluate the province, Punjab, to conduct investigations in a broader perspective by using more than two time periods to assess the actual change of this technology adoption for future policy analysis.

## 2. LITERATURE REVIEW

Improved agriculture technology adoption can increase productivity, farmer income, and food security issues. There is an expanding trend of literature review considering the impact evaluation of agriculture technology on productivity.

The study finds the impact of technology adoption on productivity for Bangladesh during 2015 by taking data from rice-growing farmers. The results show that farmers have used a high level of technology in seed variety and irrigation technology, medium level in land preparation, pest management, and fertilizer usage during the low level in weeding and harvesting. Education and landholding have a significant positive impact on technology adoption and productivity (Khatun & Haider, 2016).

The study has focused on Asian countries to cater to food security in the region by considering rice crops in Bangladesh. The study also highlights the share of rice in Asian economies and household food consumption reducing over time. Rice is the largest basis of calories for a significant majority of poor consumers. A strategy has been presented at the international forum for price control and sustainability over time (Timmer, 2010).

The study examines and evaluates the productivity development in French agriculture from 2002 to 2015 by taking into account total factor productivity as well as changes in technology and efficiency. Field crop farms, dairy farms, beef farms, sheep and goat farms, and mixed farms are the five forms of farming. The study assessed technological change and efficiency by using various factors. The most productive factor is cropping farm (Adom & Adams, 2020).

The study examines the productivity change in five different forms of farming in France between the years of 2002 and 2015: field crop farms, dairy farms, beef farms, sheep and goat farms, and mixed farms. The study also assessed TFP change, together with its technical and efficiency components, as well as additional efficiency change components, for each of the five sub-samples. In order to compare technological evolution, Fare Primont has also been used as a meta-frontier framework. TFP advancement was seen in all forms of farming. The technology used by field crop farms is the most productive of all the agricultural types, according to the meta frontier study (Dakpo et al., 2019).

The low production and productivity are due to inefficient application of modern farm technologies. Adoption and efficient use of improved farm inputs are required to reduce food security. 231 samples are used in the study. The stochastic frontier, Cobb-Douglas production function and logistic approach used to determine the effects of adopting better farm inputs. The outcome demonstrates that yield is favorably and considerably impacted by the amount of land, labour, seed, chemical fertilizer, and oxen allocated. According to the logit model, market distance and crop diversity have a negative impact on the likelihood of adopting improved inputs, while extension service, information access, and cooperative membership have a positive impact (Beyene et al., 2020).

Improved seed adoption technology is positively correlated with productivity and efficiency. Differences in efficiency are responsible for some of the diversity in productivity. Efficiency is impacted by the increased seed usage since farmers frequently do not use the best amount of inputs. Its adoption has an impact on production both directly and through efficiency. Compared to recycled maize seeds, improved seeds increase productivity and efficiency, by using panel data. The findings imply that the increases in production (efficiency) that would arise from ignoring one of the two would significantly outweigh the advantages of better seeds. Although the improved seeds are more productive than conventional seeds, there are trade-offs between productivity and efficiency since farmers use the better seeds less efficiently than they do conventional seeds. It urged decision-makers to develop plans for boosting output and efficiency (Ayalew & Debela, 2019).

The household level data of 1989-2009 used to find out the impact of improved agricultural technologies on smallholders' crop productivity and welfare. The endogenous treatment effect model was applied to account for the selection bias on household technology adoption decisions. The study finds out the positive and significant impact of improved technology on crop productivity and welfare. The major factors responsible for productivity and welfare are education level, farm size, credit access, labor use, an extension program, expenditure for modern input, and asset holding. The study recommends that investment in research and development is necessary to improve productivity, food security, and the welfare of smallholder farmers (Mekonnen & Tigist, 2017).

Tetteh Anang et al., (2020) examined the farmers technological choice affects by using maize farmers data in Ghana based upon 340 sample. The probit model used for adoption decisions while double bootstrap data envelopment analysis carried out TE (Technical Efficiency) truncated regression to assess inefficiency sources. The findings shows that the farmer decision to adopt technology increases technical efficiency.

Precision agriculture technologies have a positive and significant impact on sustainable agriculture growth. These technologies included optimization of crop management, soil and resource, GPS guided machinery, remote sensing and drone delivering positive and significant impact on productivity. The study finds out that by enhancing precision agricultural technologies may lead toward increased crop yield and profitability (Mohd Javaid et al., 2022).

This study provides valuable insights into the adoption of agricultural green production technology among smallholders in China, particularly in Shaanxi Province, and its impact on rice production efficiency. The adoption rate of AGPT among the 582 rice farmers surveyed was relatively low at 15.1%. The average technical efficiency (TE) of rice production was found to be 0.312, indicating substantial room for improvement in production efficiency. A range of factors significantly influenced the adoption of AGPT by smallholders including household characteristics, family characteristics and social characteristics. Adopting AGPT significantly improved the TE of rice production, with a reported increase in TE of 18.8% to 24.5%. The study highlighted specific farmer characteristics that were associated with higher improvements in TE from AGPT adoption (Li et al., 2021).

# 3. METHODOLOGY

The current study will use the stochastic frontier method to estimate farmers' technical efficiency who used agriculture technology and innovation in panel data (2006-07 and 2017-18). The core element of modern economic theory is the assumption that behaviour may be optimized from either a producer or consumer perspective. According to economic theory, producers should maximize their output from both a technical and economic perspective:

- From a technical perspective, producers optimize by not wasting any productive resources.
- From an economic perspective, producers optimize by considering allocation problems involving prices.

Not all producers, meanwhile, are always able to solve both varieties of optimization problems. Performance at the firm or industry level, defined as the ratio of output to inputs used by production units, yielding a relative measure of performance applied to factors of production, may depend on a) production technology differences; b) production process efficiency differences; or c) production environment differences. Even though technology and the production environment are "basically the same," firms or industries may display varying productivity levels at a given time due to variations in their production efficiency.

The current study describes technology adoption efficiency, productivity, its measurement and role of technology in productivity and efficiency. The first we have calculated technology adoption efficiency that is the effects of technology adoption on farmers' technology adoption efficiency. There are two major approaches to measuring efficiency. These are SFA (Stochastic Frontier Analysis) and DEA (Data Envelopment Analysis).

The other is productivity that is defined as the relationship between the volume of output and the volume of input used to achieve a particular output. It measures the ratio of output to input. It is the center of both macroeconomic (agricultural) and microeconomic growth (economy). Increased productivity leads to increased output and income in the form of profits. Productivity indicators often fall into one of two categories: "single productivity indicators" used in combination with "multifactor productivity."

Single-factor productivity refers to the amount of output produced by a single input, such as the productivity of labour, land, or capital. The single factor productivity indicators are straightforward to interpret, comprehend, and compute since both the numerator and denominator can be stated in physical units that can be computed using a single data source. Total Factor Productivity (TFP) quantifies how effectively all the primary production inputs are distributed throughout the production process and specifies the contribution of each one. In contrast to partial productivity indicators, it gives a picture of productivity and is directly related to unit production costs and market prices.

In order to estimate the impact of agriculture technologies on productivity and efficiency, firstly the study will evaluate the average effect of the technology on farmers' productivity who adopted this technology. The impact of technology on productivity is:

$$E(Y_1 - Y_0|Z, DV = 1) = (Y_1|Z, DV = 1) - E(Y_0|Z, DV = 1) \quad (1)$$

Where E (.) is the expectation operator; $Y_1$ the yield of farmer adopted technology; $Y_0$ the yield of farmers not adopted technology while observable covariates is measured by vector Z that shows farmers personal and resource characteristics under both situations; DV is a dummy variable taking value 1 for adopted technology and 0 otherwise; To remove the biasedness, propensity score to match adopters and non-adopters have been proposed. So $E\ (Y_0|Z, DV = 1) = (Y_0|p(Z), DV = 0) = E(Y_0|p(Z))$ where p (.) is the propensity or likelihood of adopting technology based upon farmers' characteristics (Rosenbaum & Rubin, 1983).

The three-step estimation method is used to assess the impact of agriculture technology on productivity and efficiency of the farmers. Step I, a probability likelihood model is estimated for the technology adopters to generate the propensity of being an adopter. At step II, the predicted propensity score will be estimated. In the last step, the stochastic frontier model will be used for the efficiency score.

The probability that farmer $i$ is adopting technology is a function of farmers' personal and farm factors.

$$P_i(adoption) = f(farmers\ personal\ characteristics, farm\ characteristics) \quad (2)$$

For predicted probabilities scores of being adopters of technology, the following probit model will be used:

$$p(Z) = Prob(\theta_i\ = 1|Z) = Z_i\,\alpha + \epsilon_i \quad (3)$$

Where $p$ indicate the probability function while θ is the binary variable having characteristics of 1 if technology adopters 0 otherwise; Z is a set of farmer's personal and resource factors; $\boldsymbol{\epsilon}$ random error distributed with mean zero and variance one $\epsilon{\sim}N(0{,}1)$.

A firm is considered technically inefficient if it doesn't generate as much as is reasonable given the resources at its disposal. Technical inefficiency can either enhance or decrease production since more can be produced with the same amount of resources. Technical efficiency is merely one factor that contributes to increased productivity and should not be mistaken with productivity (Farrell, 1957; Nishimizu & Page, 1982; Grosskopf, 2003). On the other hand, technical efficiency denotes to "how efficiently" a farm can combine the many inputs and components of production to produce a maximum amount of output. Productivity measures the amount of production that can be generated from a given set of resources. A farm is more productive if it can produce the same amount of output with fewer resources or more output with the same amount of resources. Although the availability of superior inputs may have contributed to the increase in output, this does not necessarily imply that it is more technically efficient.

The notion of technological efficiency is based on the idea of the production frontier, which indicates the maximum output made possible by the technology. The border between distinct countries, regions, and agro-climatic zones varies as a result of technological differences.

It is a different method for estimating the frontier using parametric models. The anticipated production from this method can be seen as an expansion of productivity analysis in the conventional method and is consistent with neoclassical econometric theory. The efficiency is determined in relation to the stochastic frontier once it has been econometrically assessed for each observation. Efficiency establishes the greatest production level for production. The distance between the observed point and the frontier is used to quantify inefficiency when the firm's output is below the frontier. The cost actually exceeds the minimum frontier due to inefficiency, and the frontier indicates the possible least cost in terms of cost efficiency. The composite error term with two-sided symmetric and one-sided components is included in this method to account for statistical noise and the sensitivity issue. This method distinguishes the efficiency estimates from the standard white noise stochastic term (Lovell, 1995).

The Stochastic Frontier Analysis (SFA) for technical efficiency can be written as:

$$Q_{it} = f\,(x_{it};\beta) * \exp(\epsilon_{it}) \qquad \text{For } i = 1,2,\dots,n \text{ and } t = 1,2,\dots,T \tag{4}$$

Where the composed error is:

$$\epsilon_{it} = v_{it} - u_{it} \tag{5}$$
$$Q_{it} = f\,(x_{it};\beta) * \exp(v_{it} - u_{it}) \tag{6}$$
$$\underbrace{Q_{it} = f\,(x_{it};\beta)}_{\text{Deterministic Component}} * \underbrace{\exp(v_{it})}_{\text{Noise Component}} * \underbrace{\exp(-u_{it})}_{\text{Inefficiency Component}} \qquad (6)$$

The inefficiency effects $u_{it}$ is separate from the statistical noise $v_{it}$ in the composed error term $\epsilon_{it}$ for each farmer. The inefficiency results $u_{it}$ in equation (5) can be expressed as:

$$u_{it} = z_{it}\delta + w_{it} \tag{7}$$

Where $z_{it}$ is a (1x m) vector of independent variables. It affects a farmer's level of efficiency that fluctuates over time. $\delta$ is a (m x 1) vector of parameters to be estimated that are associated with a set of explanatory variables in the inefficiency model. $w_{it}$ is error term distributed independently truncated at -$z_{it}\delta$ with mean zero and variance $\sigma u^2$. Farmers specific technical efficiency (TE) is a combination of ratio of observed output to efficient output on frontier production function:

$$TE_{it} = \frac{Q_{it}}{Q_{it}^*} = \frac{Q_{it}}{f(x_{it};\beta) * \exp(v_{it})} = \frac{E[Q_{it}/u_{it}, x_{it}]}{E[Q_{it}/u_{it} = 0, x_{it}]}$$
$$= \exp(-u_{it}) = \exp(-z_{it}\,\delta - w_{it}) \tag{8}$$

The specification of (7) allows for TE to vary across farmers and over time. The level of efficiency is in the form of zero to one.

In empirical form, the logit model can be written as:

$$p(Z) = Prob(\theta_i = 1|Z) = \alpha_0 + \sum_{k=1}^{8} \alpha_k Z_k + \epsilon_i = \alpha_0 + \alpha_1 ISA + \alpha_2 FMA + \alpha_3 WITA + \alpha_4 FUA + \alpha_5 AIEA + \alpha_6 ISMAA + \alpha_7 MPAA + \epsilon_i \tag{9}$$

The Cobb-Douglas function for the stochastic frontier model is written in the form:

$$logY_i = \beta_O + \beta_1 \log(IS) + \beta_2 \log(FM) + \beta_3 \log(WIT) + \beta_4 \log(FU) + \beta_5 \log(AIE) + \beta_6 \log(ISMA) + \beta_7 \log(MP) + v_i - u_i \tag{10}$$

The inefficiency model can be written as follows:

$$V_i = \delta_0 + \delta_1 AG + \delta_2 FZ + \delta_3 EDUF + \delta_4 FS + \delta_5 FE + \delta_6 EMP + \delta_7 LO + \delta_8 OA \tag{11}$$

Where $Y_i$ represents the yield produced by the ith farmer; IS represents the Improved/Hybrid Seed; FM represents the Farm Mechanization; WIT denotes the Water Irrigation Technologies; FU denotes the Fertilizer Usage; AIE represents Access to Improved Electricity; ISMA represents the Internet/Social Media Access; MPA represents the Mobile Phone Access; AG denotes the Age of Farmer; FZ represents the Family Size (Number); EDUF represents the Education of Farmer (years of schooling); FS represents the Farmer Specialization; FE represents the Experience of Farming; EMP represents the Household Employment Status; LO represents the Livestock Ownership; OA represents the Operational Area (Acres).

# 4. RESULTS AND DISCUSSION

This section represents results of productivity and efficiency models estimated for productivity and efficiency impact for base period and end line. The maximum likelihood estimates of the stochastic frontier production and efficiency model parameters are estimated using Stata 16.0 version and applied a two-stage approach in our analysis. We have estimated the stochastic half-normal frontier production function at the first stage, while we have estimated f0arm-specific efficiency determinants at the second stage. For comparison, both Ordinary Least Square (OLS) and Frontier Production Function have been estimated to determine the agriculture technologies adoption effects on productivity in the area.

The farm mechanization and fertilizer usage having positive significant impact on productivity during base period 200607. In comparison, the frontier production function indicates that only fertilizer adoption technology has a positive and significant role in productivity. It means if there is any change in fertilizer usage, then productivity positively changes by 0.017. The access to improved electricity adoption technology has a significant (5% level of significance) negative impact on productivity during 2006-07. The results are presented in Table 1.

**Table 1:** Parameter Estimates of the Stochastic Frontier Production

| Agriculture Technologies | 2006-07 | | 2018-19 | |
|---|---|---|---|---|
| | OLS | Frontier Function | OLS | Frontier Function |
| | Coefficients | | | |
| Improved/Hybrid Seed (IS) | 0.040 | 0.015 | 0.051*** | 0.051*** |
| | (0.035) | (0.024) | (0.012) | (0.012) |
| Farm Mechanization (FM) | 0.048*** | 0.002 | 0.065*** | 0.065*** |
| | (0.015) | (0.011) | (0.012) | (0.012) |
| Water Irrigation Technologies (WIT) | - | - | 0.062*** | 0.062*** |
| | - | - | (0.012) | (0.012) |
| Fertilizer Usage (FU) | 0.029* | 0.017* | 0.090*** | 0.090*** |
| | (0.013) | (0.010) | (0.016) | (0.016) |
| Access to Improved Electricity (AIE) | 0.017 | -0.038** | 0.035** | 0.035** |
| | (0.022) | (0.017) | (0.015) | (0.015) |
| Internet/Social Media Access (ISMA) | 0.037 | 0.034 | 0.030** | 0.030** |
| | (0.036) | (0.025) | (0.013) | (0.013) |
| Mobile Phone Access (MP) | 0.057 | 0.022 | 0.055*** | 0.055*** |
| | (0.038) | (0.027) | (0.018) | (0.018) |
| Constant | 3.413*** | 3.673*** | 3.191*** | 3.195*** |
| | (0.010) | (0.012) | (0.026) | (0.091) |
| | | -6.351*** | | -3.706*** |
| | | (0.344) | | (0.055) |
| | | -2.509*** | | -10.743 |
| | | (0.075) | | (47.29) |

Source: Authors own Estimation using data set of 2006-07 & 2018-19. The values in parentheses presents the standard errors, while asterisks describe significance level (10%, 5%, 1%) respectively.

The seven technologies utilized in the study; however, all play positive and important roles in productivity during the end line (follow-up survey) of 2018–19 for OLS and frontier production function. It suggests that the adoption of certain agricultural technologies plays a positive impact in determining productivity. According to the OLS estimations, adoption of improved/hybrid seeds, farm mechanization, water irrigation technologies, fertilizer use, and mobile phone access all have a positive and substantial impact on productivity. The area's productivity in 2018–19 is positively and significantly impacted by access to improved electricity adoption and internet/social media access adoption technologies (5% level of significant).

Results from the stochastic frontier production function between 2018–19 reveal that adoption of better or hybrid seeds, agricultural mechanization, water irrigation technologies, fertilizer use, and mobile phone availability all play a significant influence in productivity. While the adoption of greater access to electricity and the internet/social media are significant at a 5 percent level, all of these technologies are positive and significant at a 1 percent level of significance.

The stochastic frontier production results show that if there is a change in improved/hybrid seed technology, there is a positive change of productivity of 0.051 while farm mechanization has 0.065, respectively. Water irrigation technologies and fertilizer usage have a positive and significant impact of 0.062 and 0.090, respectively. Access to improved electricity, internet/social media access, and mobile phone access also positively and significantly impact productivity. These technologies positively affect productivity by 0.035, 0.30, and 0.55, respectively.

The technical efficiency of the sampled farmers of the local area has been assessed by applying the technical efficiency equation. We have estimated technical efficiency for both periods; 2006-07 base and 2018-19 end-line respectively. Technical inefficiency exists in both periods, but the level of technical inefficiency is higher during the base period 2006-07. On the other hand, it has reduced during the end line period 2018-19. There is a change of adopters from 2006-07 to 2018-19 due to which there are positive effects of technical efficiency level in the district Faisalabad, Pakistan.

The parameter estimates of variables used in technical efficiency are presented in Table 2. The technical efficiency results show that during the base year (2006-07), the age of the farmer, education of the farmer, and operational area have a positive and significant role in technical efficiency. It indicates that these variables increase technical efficiency. The farmer education and farmer operational area have a positive and significant role in technical efficiency. The previous studies confirm the results of farmer education's positive effect on technical efficiency (Jamison & Moock, 1984; Mechri et al., 2017).

On the other hand, the significant negative factors responsible for technical inefficiency are farmer specialization, farming experience, household employment status, and livestock ownership in the area during the base period (2006-07). The results show that farmer specialization does not have any role in technical efficiency during 2006-07 as it reduces technical efficiency like the experience of farming, household employment, and livestock ownership.

The end-line survey (2018-19) results show that family size, household member employment, and livestock ownership have a positive and significant role in technical efficiency determination in the district Faisalabad, Pakistan. The family size variable indicates that as farmer family size increases, there is an increase in its technical efficiency level due to increasing usage of new/improved technology adoption to increase agriculture productivity (Boru et al., 2015).

**Table 2:** Parameters Estimates of Efficiency Effects Model

| Variables | 2006-07 | 2018-19 |
|---|---|---|
| | Coefficients | |
| Age of Farmer | 0.002*** | 0.0003 |
| | (0.001) | (0.0004) |
| Family Size (Number) | -0.004 | 0.0041** |
| | (0.004) | (0.002) |
| Education of Farmer (Years of Schooling) | 0.003** | 0.0012 |
| | (0.001) | (0.001) |
| Farmer Specialization | -0.021** | -0.0044 |
| | (0.010) | (0.006) |
| Experience of Farming | -0.002** | -0.0005 |
| | (0.001) | (0.0004) |
| Household Employment Status (1,0) | -0.046*** | 0.0255*** |
| | (0.010) | (0.006) |
| Livestock Ownership | -0.026** | 0.0126** |
| | (0.014) | (0.006) |
| Operational Area (Acre) | 0.005*** | 0.0013*** |
| | (0.001) | (0.0004) |
| Constant | 0.739*** | 3.3967**** |
| | (0.025) | (0.012) |

Source: Authors own Estimation using data set of 2006-07 & 2018-19. The values in parentheses presents the standard errors, while asterisks describe significance level (10%, 5%, 1%) respectively

The financial strength of farmers also has a positive and significant role in technical efficiency determination. The farmer's financial stability is shown by the farmer's family members' employment status and livestock ownership. These variables (family member employment, livestock ownership) have a positive and significant role in technical efficiency during 2018-19. Farmer agriculture operational area (acres) also has a positive and significant role in technical efficiency determination. The stochastic frontier production function's overall findings indicate that the new and better agricultural technology used in the study has a favorable and significant impact on productivity. In the district of Faisalabad, Pakistan, during the 2018–19 academic year, the technical efficiency result reveals that family size, employment of household members, livestock ownership, and farmer operational area have a positive and substantial effect in enhancing technical efficiency.

## 5. CONCLUSION AND POLICY IMPLICATIONS

The study describes the role of agriculture technologies adoption in the district on productivity and efficiency during 2006-07 (base year) and 2018-19 (end-line), respectively. A very few studies conducted in Pakistan catering technologies adoption impact on productivity and efficiency. Some studies investigated single or two technologies' impact on productivity and efficiency. In contrast, this study includes seven types of technologies being used in the sector and announced by the government to assess the effects of this technology on productivity and efficiency in the district. The sample for the survey is 720 farmers from two tehsils for each survey (base year & end line) collected through field survey during wheat harvesting season from the district.

Agriculture productivity and efficiency have an important role in the agriculture sector and in meeting food security. Various factors are responsible for their determination to boost productivity. Technical efficiency measures the influencing factors accountable for its determination in the area.

The fertilizer usage technology adoption during 2006-07 has only a positive and significant role in productivity using the stochastic frontier production model. The low or less impact being observed during this period because of the low technology adoption rate in the area and other factors beyond this study may prevail for its low impact. The technologies used in this study showed a significant impact on dependent variables i.e. productivity during 2018-19. These seven technologies have significance at various levels and positively affect productivity in the Faisalabad district (Pakistan). The technologies that have positive and significant impacts on productivity are improved/hybrid seed, farm mechanization, water irrigation technologies, fertilizer usage, access to improved electricity, internet/social media, and mobile phone access.

The technical efficiency positive influencing factors during 2006-07 are the farmer's age, education of farmer and farmer agriculture operational area while some negatively impacting efficiency are farmer specialization, the experience of farming, household family member employment and livestock ownership. While on the other hand, during 2018-19, family size, household family member employment, livestock ownership, and operational area increase technical efficiency.

The current study as overall recommends the following policy recommendations for future agriculture productivity and growth:

- The agriculture extension officer must be in contact with farmers and conduct awareness campaign for new and improved agriculture technologies.
- The farmer income and welfare are strongly linked with these technologies' adoption. The adopters have higher income level as compared to non-adopters.
- The government must introduce new and improved agricultural technologies at subsidized to increase adoption level to increase productivity.

The current study is limited to only one district dealing with two tehsils sample data, in future, the research may extend to more districts with more variables. In addition, in future, the same kind of analysis could be extended for four provinces of Pakistan and a comparison can be done on the basis of results.

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## REFERENCES

Abri, A. G., & Mahmoudzadeh, M. (2015). Impact of information technology on productivity and efficiency in Iranian manufacturing industries. Journal of Industrial Engineering International, 11(1), 143–157. https://doi.org/10.1007/s40092-014-0095-1.

Adom, P. K., & Adams, S. (2020). Decomposition of technical efficiency in agricultural production in Africa into transient and persistent technical efficiency under heterogeneous technologies. World Development, 129, 104907. https://doi.org/10.1016/j.worlddev.2020.104907.

Aikaterini Kokkinou (2010). A Note on Theory of Productive Efficiency and Stochastic Frontier Models, European Research Studies, Journal Volume XIII Issue 4, 109-118. https://doi.org/10.35808/ersj/302

Asante, B. T. (2020). Farm household access to agricultural services in northern Ghana. Heliyon, Volume 6, Issue 11.

Ayalew, Z., & Debela, L. (2019). The joint impact of improved maize seeds on productivity and efficiency: implications for policy, working paper, University of Goettingen, www.uni-goettingen.de/globalfood

Beyene, T., Mulugeta, W., & Merra, T. (2020). Technical efficiency and impact of improved farm inputs adoption on the yield of haricot bean producer in Hadiya zone, SNNP region, Ethiopia. Cogent Economics & Finance, 8, 1833503. https://doi.org/10.1080/23322039.2020.1833503

Boru, D., Schwartz, M., Kam, M., & Degen, A. A. (2015). Effects of family size and wealth on size of land cultivated by borana pastoralists in Southern Ethiopia. In Human Ecology (Vol. 43, Issue 1). https://doi.org/10.1007/s10745-014-9711-3

Coelli, T.J., Rao, D.S.P., O Donnell, C.J., and Battese, G.E. (2005). An introduction to efficiency and productivity analysis. 2nd ed. New York, NY, United States: Springer. https://doi.org/10.1007/b136381

Farrell, M. J. (1957). The Measurement of Productive Efficiency. Journal of the Royal Statistical Society. Series A (General), 120(3), 253. https://doi.org/10.2307/2343100

Fatima Khatun & Mohammed Ziaul Haider, 2016. Impact of Technology Adoption on Agricultural Productivity, Journal of Agriculture and Crops, Academic Research Publishing Group, vol. 2(9), pages 87-93, 09-2016.

Grosskopf, S. (2003). Some remarks on productivity and its decompositions. Journal of Productivity Analysis, 20(3), 459–474. https://doi.org/10.1023/A:1027364119672

Jamison, D. T., & Moock, P. R. (1984). Farmer education and farm efficiency in Nepal: The role of schooling, extension services, and cognitive skills. World Development, 12(1), 67–86. https://doi.org/10.1016/0305-750X(84)90036-6

Li, C., Shi, Y., Khan, S. U., & Zhao, M. (2021). Research on the impact of agricultural green production on farmers' technical efficiency: evidence from China. Environmental science and pollution research international, 28(29), 38535–38551. https://doi.org/10.1007/s11356-021-13417-4

Lovell, C. A. K. (1995). Stochastic Frontier Analysis : An Econometric Approach. European Journal of Opertational Research, 80(January), 452–461.

Mechri, A., Lys, P., & Cachia, F. (2017). Productivity and Efficiency Measurement in Agriculture. Food and Agriculture Organization of the United Nations, February, 77. http://gsars.org/wp-content/uploads/2017/02/TR-17.02.2017-Productivity-and-Efficiency-Measurement-in-Agriculture.pdf

Mekonnen, & Tigist. (2017). Productivity and household welfare impact of technology adoption: Micro-level evidence from rural Ethiopia. MERIT Working Papers.

Mohd Javaid, Abid Haleem, Ravi Pratap Singh, Rajiv Suman (2022). Enhancing smart farming through the applications of Agriculture 4.0 technologies, International Journal of Intelligent Networks, Volume 3, 2022, Pages 150-164.

Mohd Javaid, Abid Haleem, Ravi Pratap Singh, Rajiv Suman, Ernesto Santibañez Gonzalez (2022). Understanding the adoption of Industry 4.0 technologies in improving environmental sustainability, Sustainable Operations and Computers,Volume 3,Pages 203-217, https://doi.org/10.1016/j.susoc.2022.01.008.

Nguezet, P. M. D., Diagne, A., Okoruwa, V. O., & Ojehomon, V. (2011). Impact of improved rice technology (NERICA varieties) on income and poverty among rice farming households in Nigeria: A local average treatment effect (LATE) approach. Quarterly Journal of International Agriculture, 50(3), 267–291. https://doi.org/10.22004/ag.econ.155535.

Nishimizu, M., & Page, J. M. (1982). Total factor productivity growth, technological progress and technical efficiency change: dimensions of productivity change in Yugoslavia, 1965-78. Economic Journal, 92(368), 920–936. https://doi.org/10.2307/2232675.

OECD. (2001). Measuring Productivity - OECD Manual. Measuring Productivity - OECD Manual. https://doi.org/10.1787/9789264194519-en

Rosenbaum, P. R., & Rubin, D. B. (1983). The central role of the propensity score in observational studies for causal effects. Biometrika, 70(1), 41–55. https://doi.org/10.1093/biomet/70.1.41

Solow, R. M. (1957). Technical Change and the Aggregate Production Function. The Review of Economics and Statistics, 39(3), 312–320.

Tadesse, Bedassa & Krishnamoorthy, S. (1997). Technical Efficiency in Paddy Farms of Tamil Nadu: An Analysis Based on Farm Size and Ecological Zone. Agricultural Economics. 16. 185-192. 10.1016/S0169-5150(97)00004-2.

Timmer, C. P. (2010). The Changing Role of Rice in Asia's Food Security. *ADB Sustainable Development*, *15*, 1–18. http://www.adb.org/sites/default/files/pub/2010/adb-wp15-rice-food-security.pdf