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Re-examining the relationship between Farm size and Technical efficiency: A Stochastic Production Frontier Approach

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ABSTRACT
This study focused on the relationship between farm size and technical efficiency using stochastic production approach. Well-structured questionnaire was allotted to 120 maize farmers and analyzed using descriptive statistics, stochastic production frontier and Tobit regression. Stochasticproductionfrontieranalysisshowsthatthe meantechnicalefficiency oftherespondents is0.75.Theanalysisalsoshowed that farming year experience, Mechanization and Pesticide quantity affects technical efficiency of farmers negatively while Years of formal education and Fertilizer quantity affect technical efficiency positively. The study shows that there is a positive relationship between farm size and technical efficiency in all the farm size classes and affected by the education and experience of marginal and small scale farmers and level of inputs used by medium and large scale farmers. The study recommends policy options that favour the training and education of marginal and small scale farmers through extension agents and subsidization of input prices.
Keywords: *Technical efficiency, Farm size, Stochastic Production Frontier, Tobit Regression.*

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I. Introduction

Many variables, such as farm inputs, farm size, irrigation, credit availability, and others, have been used to explain farm technical efficiency. Academics have spent a lot of time studying the relationship between farm size and productivity, often coming up with opposing viewpoints, which has helped us to better grasp the relationship. The majority of early technical efficiency studies found an inverse association between productivity and farm size. (Sen 1962, 1964; Khusro 1968; Hanumantha Rao 1966; Saini 1971; Berry and Cline, 1979; Barrett, 1996). As a result of technical involvement in agriculture, the perspective altered, resulting in a direct relationship between the two variables, which is supported by literature. (Chadha 1978; Sen and Rudra1980; Bagai and Soni 1983, Singh et al. 2017).

According to Helfan et al. (2004), the link between farm size and efficiency is not linear, meaning that efficiency decreases at first and then rises as the farm grows in size. When Materson (2007) utilized the Non-parametric Technical Efficiency Coefficient, he found a U-shaped relationship between farm size and technical efficiency. He also observed a declining relationship, in which technical efficiency increases as farm size grows to a point where it continues to decline, which Rahman et al. also corroborated (2009). However, Njeru (2020) found that there is diversity in technical efficiency in each farm category based on the farmer, with the most variation among large-scale farmers in his study: Technical efficiency among wheat farmers in Kenya.

This study focused on the re-examining the relationship between farm size and technical efficiency and also the variables affecting technical efficiencies in each farm classes (marginal farms, small farms, medium farms and large farms

II. Materials And Methods

2.1 Data collection

The study was carried out in Ogbomoso, a city in Oyo State, South-Western Nigeria. Ogbomoso population was roundly 1.2 million (population.city, 2015) with population density of 253/km^2. The town is found within the derived savanna region and has an average high uniform temperature, moderate to heavy rainfall, and high humidity. Most of the dwellers of the area practised farming and their contriubtions in terms of food production cannot be overestimated. The predominant crops include; maize, cassava, yam, watermelon and cash crops like cashew, palm trees and mango. Ogbomoso Agricultural zone is one of the four agricultural zones in Oyo State. Ogbomoso consists of Ogbomoso North, Ogbomoso south, Surulere, Orire, Ogo-oluwa Local Government Areas (LGAs). Each LGA represents a block and each block has eight (8) cells according to Agricultural Development Project (ADP). The zone was purposively chosen because this research focuses on farming households of which the major occupation of people in this area is farming. The data for the study was collected in 2018 from 110 farming household heads in Ogbomoso through the use of well-structured questionnaires using a multi-stage sampling technique. The sampling process was staged in four. The first involved a random selection of two local governments in Ogbomoso. The second involved choosing two wards each randomly from the two local governments (i.e 4 wards). The third involved randomly selecting two villages each from the wards selected (i.e 8 villages) and lastly 15 farmers were selected in each villages using simple random sample techniques. A total of 110 farming households were surveyed. The sampling unit for the study was household head.

2.2 Descriptive Statistics

Descriptive analysis was used to lay emphasis on the socio-economic characteristics of the maize farmers in the study region. The analysis was presented in form of frequency tables and bar chats. The data collected from the rural household farmers include social economic characteristics like age, gender, sex, household size, level of education and soon.

2.3 Stochastic ProductionFrontier

Forthepurposeofthisresearch,technicalefficiencywascapturedusingthestochasticproduction frontier analysis invented by Battese and Coelli (1995) and used by Yao and Liu (1998) as well as Oladeebo (2006) and this helps to calculate the technical efficiency of maize farmers in this studyarea.

The production frontier model without random component can be written as:

$Y_i=f(x_i;\beta).TE_i$

Where y_i is the observed scalar output of the producer i ,i=1,..I, x_1 is a vector of N inputs used by the producer i, $f(x_i, \beta)$ is the production frontier, and is a vector of technology parameters to be estimated.

TE_i denotes the technical efficiency defined as the ratio of observed output to maximum feasible output. $TE_i = 1$ shows that the i-th firm obtains the maximum feasible output, while $TE_i < 1$ provides a measure of the shortfall of the observed output from maximum feasible output.

$Yi=f(Xi:\beta) \exp (Vi-Ui)$ i=1,2….,N

Where, Yi = Production of ith maizefarmers,

Xi = Vector of input quantities of ith maize farmers,

B = Vectors of unknown parameters,

Vi = Assumed to account for random factors such as weather risk and measurement error,

Ui = Due to technical efficiency

For the maize farmers, the stochastic frontier production model is stated explicitly as;

$\ln Y= \ln\beta o + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 v_i-u_i$

Where:

Y = Output (kg of maize) of the ithvalue

X_1 = Fertilizer quantity(liters)

X_2 = Herbicide quantity (liters)

X_3 = Pesticide quantity(liters)

X_4 =Years of formal education (years)

X_5= labor (mandays)

e = error term.

Vi = decomposed error term measuring technical efficiency of the farmer

Ui = the inefficiency component of the error term

Inefficiency model

The inefficiency model was defined as follows:

$Ui = \sigma_0 + \sigma_1 Z_1 + \sigma_2 Z_2 + \sigma_3 Z_3 + \sigma_4 Z_4 + \sigma_5 Z_5 + \sigma_6 Z_6$

Where

Ui = inefficiency effect

Z_1 = Years of formal education (years) Z_2 = Fertilizer quantity (litres)

Z_3 = Access to credit (1=yes, 0=no)

Z_4 =Labour quantity (man days)

Z_5 = Years of experience(years)

Z_6 = herbicides quantity (litres)

Z_7 = seed quantity (kilogram)

Z_8 =mechanization (1=yes, 0= no)

III. RESULTS ANDDISCUSSION

3.1. Socio-Economics Characteristics

The Table 1 below reveals that there is no difference in the ages, sex and marital status of the farmers in the three classes of farm size but farmers in the large size are more educated, experienced and adopt mechanized farming. The extension visit, cooperative membership and access to credit of the farmers increase progressively as we move from marginal farm size to the medium/large scale farm. The primary occupation of the large scale farmers were only farming whilemarginalandsmallscalefarmersdiversifytheirincomethroughbeingengagedinothernon- farmingactivities

3.2. Analysis of the relationship between farm size and technicalefficiency

Therelationshipbetweenfarmsizeshasbeenalongtimeresearchissuesforresearchers.Theresult of this research displayed in figure 1shows a linear relationship between farm size and technical efficiency which is in consonance with the findings of Bhatt et al (2014) and also a positive relationship between farm sizes and technical efficiency which is contrary to many findings such as (Fan & Chan- Kang, 2003); (Shanmugam, 2003); (Helfand et al., 2004); (Shanmugam &Venkataramani, 2006); (Hazell,etal., 2007);(Thapa,2007);(Kumar&Mittal,2010);(Chand, etal., 2011)].amongothers but in consonance with the findings of (Bojnec, Latruffe,2007).

The major reasons for the positive linear relationship between farm size and technical efficiency based on this study are shown in table 4:

Years of formal education

The coefficient of level of education was negatively related to inefficiency and significant at P=.10% level of significance. A year increase in the number of years of education brings about a 0.45% reduction in technical inefficiency. The implication of this is that inefficiency of resource useinthestudyareadecreaseswiththelevelofeducation.The likelyimplicationofthisisthatthe moreeducatedahouseholdheadis,themoreattentionhe/shepaystoeffectivemanagementof their farms. Presumably, their enhanced ability to acquire technical knowledge makes them closer to the frontier output. Besides, farmers who had some level of education respond readily to the use of improved technology, such as application of fertilizers, use of pesticides and improved planting materials, thus producing closer to the frontier. The negative coefficient agrees with the findings of Okoruwa et al (2012).

Farming year experience

The positive coefficient of the years of experience in maize farming which is statistically significant at 1% implies that farmers with longer years of experience in maize farming are more technicallyinefficientthanthosewithfeweryears ofexperience.Thiscouldbeexplained interms of the adoption of modern technology. Farmers who have been growing maize for years may tend to be conservative, while younger and new maize farmers may be more receptive to modern and newly-introduced agricultural technology. If years of farming experience increases by 1 year, the technical in efficiency of the farmer increases by 0.43% although age was not significant, the positive coefficient implies that older farmers in Oyo State are less efficient. However, it is possible for maize farming experience and age to be correlated and to produce the results in this study. This is an important possibility (multi-colinearity), as similar results were reported by Ajibefun et all(2002).

Access to Credit

The result shows that access to credit is positively related to technical efficiency with the coefficientshowingthatapercentageincreasetoaccesstocreditwillreducetechnicalinefficiency by 1% but it is statistically insignificant. This is in consonance with the findings of Njeru (2010). This implies that farmers who have access to credit are able to adopt new innovations due to availability of capital, and they are also able to use recommended level of input which will affect productivitypositively**.**

New technology adoption and mechanization

The result shows a negative relationship between technology and machinery adoption and technical inefficiency i.e. the higher the rate of mechanization, the better the rate of technical efficiencyoffarmersandit isstatisticallysignificantat1%.Thisisinconsonancewiththefindings of Adewuyi et al(2013).

3.3. Factors Influencing Technical Efficiency in each Farm Classes

Most researches on relationship between farm size and technical efficiency did not take a look at the factors responsible for the technical efficiencies in each farm classes. According to this study, the factors responsible for farmers' inefficiency technically in each farm class are explained below:

3.3.1. Factors affecting technical efficiency of Marginal Farms
The major factors responsible for the technical inefficiencies of marginal farmers are shown in table 5 which are:

Farming year experience
The positive coefficient of the years of experience in maize farmingwhich is statistically significant at 5% implies that farmers with longer years of experience in maize farming are more technically efficient than those with fewer years of experience. If years of farming experience increases by 1 year, the technical in efficiency of the farmer increases by 0.11%. Similar results were reported by Ajibefun et all (2002).

Years of formal education
The degree of education coefficient was shown to be negatively connected to inefficiency and positively related to technically efficiency, with a significance level of P=1%. An extra year spent in school leads to reduction in technical inefficiency by 0.22. As a result, resource inefficiency in the study area diminishes as education increases. This suggests that the more educated a household head is, the more attention he or she devotes to good agricultural management. Their improved ability to acquire technical information, presumably, brings them closer to frontier output. Furthermore, farmers with some education respond well to increased technologies, such as fertilizer application, pesticide treatment, and improved planting materials, resulting in production closer to the frontier. Wakali's results are supported by the negative coefficient (2012).

Pesticide quantity
The table above shows a positive relationship between technical efficiency and pesticide quantity applied. This means that the higher the quantity of fertilizer applied, the higher the technical efficiency.ThisisinconsonancewiththefindingsofKyei(2013).Pesticidequantityisstatistically significantat1%andwithacoefficientof0.79meaningonepercentageincreaseinpesticideusage will lead to 0.79% increase in technicalefficiency.

Herbicides quantity
The table also shows a negative effect of the amount of herbicides applied to technical efficiency of farmers. It is significant at 1% level of significance. This result is in contrary to the expected result and also to the findings of Ayinde et al (2016). This may be as a result of utilization of the herbicides above the recommended level which may likely cause a decline in technical efficiency if herbicides quantity is increased.

3.3.2. Factors affecting technical efficiency of small farms
The major factors responsible for the technical inefficiencies of small scale farmers are shown in table 6 which are:

Years of formal education
The coefficient of level of education was negatively related to inefficiency and positively related to technically efficiency and significant at P=1% level of significance. A year increase in the number of years of education brings about a 0.26% reduction in technical inefficiency. The implication of this is that inefficiency of resource use in the study area decreases with the levelof education. The likely implication of this is that the more educated a household head is, the more attention he/she pays to effective management of their farms. Presumably, their enhanced ability to acquire technical knowledge makes them closer to the frontier output. Besides, farmerswhohadsomelevelofeducationrespondreadilytotheuseofimprovedtechnology,such as application of fertilizers, use of pesticides and improved planting materials, thus producing closer to the frontier. The negative coefficient agrees with the findings of Wakali(2012).

Mechanization and technology adoption
The result shows a negative relationship between technology and machinery adoption and technical inefficiency i.e. the higher the rate of mechanization, the better the rate of technical efficiencyoffarmersanditisstatisticallysignificantat1%.Thisisinconsonancewiththefindings of Adewuyi et al(2013).

3.3.3. Factors affecting technical efficiency of medium/large farms
The major factors responsible for the technical inefficiencies of medium and large scale farmers are shown in table 7 which are:

Years of education
The result of the Tobit regression shows that there is a negative relationship between years of formal education of the farmers and technical efficiency significant at 10% and also a 1% decrease in years of education will lead to 0.12% increase in technical efficiency. This is in accordance with Marlaine E. and Lawrence J (1979**).**

Farm Experience
The result shows the relationship between farm year experience and technical efficiency to be negative at 5% level of significance. The fact that improvement in education reduces maize production efficiency leaves a worry as it does not conform to the a priori expectation. This may probably mean that non- formal education

provided by extension officers, which directly impinges positively on the production process, would have been better captured in the model instead. This is in agreement with Idris Akanbi et al (2015)

Mechanization

The result shows a negative relationship between technology and machinery adoption and technical inefficiency i.e. the higher the rate of mechanization, the better the rate of technical efficiencyoffarmersand itisstatisticallysignificantat1%.Thisisinconsonancewiththefindings of Adewuyi et al(2013).

Fertilizer and Seed quantity

The result shows a positive relationship between fertilizer and Seed quantity and technical efficiency which shows that the higher the rate of fertilizer application and seed application the higher the productivity of the farmers and hence their efficiency. They are both statistically significant at 1% level of significance.

Pesticides and Herbicides quantity

The result shows a negative relationship between pesticides and herbicides application and technical efficiency which is completely different from the expected result that there should be a positive relationship between them. This might be as a result of over-utilization of the pesticides and herbicides which might affect the productivity of the maize. They are both statistically significant at 1% level of significance and in accordance with the findings of Sri Fajar and Aulia (2018)**.**Conclusively, large scale farmers' technical efficiencies are mainly affected by their level of input use while marginal and small scale farmers are mainly affected by their experience and education. Also the most significant factor affecting technical efficiency in all the farm sizes is years of formal education which shows that educated farmers are likely to be more efficient due to the fact that inputs will be used to the recommended level and also ease in the use of new technology and adoption of new innovations. This conforms to the finding of Okoruwa et al, (2011).

IV. CONCLUSION AND RECOMMENDATIONS

It can be concluded through this research that most of the respondents are literate, male, mid-agedwithalotofexperienceinthemaizeproductionand itwas realizedthat mostofthe farmershadlargehouseholdsize,lowextensionvisit,practicedmixedcropping,usedbothfamily and hired labor and inherited their farmlands.

Itwasdeducedfromthestochasticfrontieranalysisthatthetechnicalefficiency of the average respondent in the study area can be increased by 25% with the technical inefficiencies due to many factors such as age, access to capital and credit, cooperative membership, year of farming experience, level of education, extension agents' visit, technology adoption and mechanization. Also, theordinaryleastsquareregressionshowedapositiverelationshipbetweenfarmsizeandtechnical efficiency. It was revealed in the study that there is a the relationship between farm size and technical efficiency in all the farm size classes was positive and was affected mainly by the education and experience of marginal and small scale farmers and level of inputs used by medium and large scale farmers.

The study recommends that there is a need for policies and programs that will help to enhance productivity andultimately increasing technical efficiencies of farmers to be put in place, the following recommendations areproffered:

1) Agricultural policy that would encourage the participation of young people should be formulated as it was deduced that the mean age of farmers in all the classes of the farm size was high

2) The continuity in mixed cropping system should be encouraged in all the categories of farm sizes as it helps in preventing pest building during off –season and also source of risk management.

3) Training and education of marginal and small scale farmers through extension agents should be done effectively because small scale farmers efficiency are mainly affected by their education and experience

4) Input cost should be subsidized and regulated as one of the major determinants of technical efficiency of medium and large scale farmers in this study area is their level of input use.

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TABLES AND FIGURES

Table 1: Comparison of the socio-economic characteristics of farmers in each farm classes

Socio-economic Characteristics	Marginal farms (<1ha) (n=32)	Small farms (1ha – 2ha) (n=43)	Medium/Large farms (>2ha)(n=35)	Total population (n-110)
Sex	Male-93.75% Female –6.25%	Male – 95.35% Female –4.65%	Male – 97.14% Female –2.86%	Male –95.45% Female-4.55%
Age	47years(mean)	48years(mean)	47years(mean)	47years (mean
Marital status	Married –81.25% Single –18.75% Divorced – 0%	Married –97.67% Single –2.33% Divorced –0%	Married –82.86% Single –14.26% Divorced –2.86%	Married -88.18% Single-10.91% Divorced –0.91%
Years of formal education	8years (mean)	9years (mean)	13years(mean)	10years(mean)
Household size	6 (mean)	7 (mean)	8 (mean)	8 (mean)
Farming experience	20 years (mean)	24 years(mean)	30years (mean)	25years (mean)
Primary occupation	Farming – 75% Non-farming – 25%	Farming-79.07% Non-farming20.93%	Farming – 100%	Farming- 83.64% Non-farming-16.36%
Extension visit	Yes – 31% No –69%	Yes –51.16% No –48.82%	Yes –54.29% No – 45.79%	Yes- 46.36% No –53.64%
Access to credit	Yes –18.75% No –81.25%	Yes- 27.91% No –72.09%	Yes –45.71% No – 54.29%	Yes- 30.91% No-69.09%
Cooperative membership	Yes –43.75% No –56.25%	Yes –46.51% No – 53.49%	Yes –57.14% No – 42.86%	Yes-49.09% No- 50.91%
Fertilizer use	Organic –25% Inorganic – 68.75% None –6.25%	Organic –30.33% Inorganic–84.37% None -3.43%	Organic-30.3% Inorganic- 88.57% None –0%	Organic-31.82% Inorganic-82.73% None-2.13%
Labor type	Hired –3.13% Family – 28.13% Both –68.74%s	Hired – 9.30% Family –2.33% Both – 88.37%	Hired – 8.57% Family –2.86% Both – 88.57%	Hired-7.27% Family-10% Both-82.73%
Machinery & Technology adoption	Yes–12.10% No –87.50%	Yes –26.28% No –73.72%	Yes –57.14% No – 42.86%	Yes- 28.18% No –71.82%

Source: Field survey (2018)

Table 2: Distribution of Farmers by Technical efficiencies

Technical efficiency	Frequency	Percentage
0.2 -0.5	18	16.36
0.5-0.8	44	40.00
Between 0.8 & 1.0	48	43.64
Total	110	100.00
Mean (0.75)	S.D (0.17)	

Source: Field Survey 2018

Table 3: Comparison of technical efficiency of classes of farmsizes

Farmsize/ technical Efficiency	Marginal farm size	Small farm size	Medium&largefarmers	All farmers
Mean value	0.70	0.74	0.77	0.75
Maximum value	0.88	0.97	0.98	0.98
Minimum value	0.29	0.39	0.59	0.29
Highest range	< 0.5	0.7 – 0.9	0.9 – 1.0	0.8 – 1.0

Source: Field survey (2018).

Table 4: Factors Affecting technical efficiency of all classes of farm size farmers

Technical efficiency	Coefficient	Std. Err	T	P>|z|
Years of education	.0090586	.0037762	2.40	0.019**
Farming experience	.0025868	.0012051	-2.15	0.035**
Access to credit	-.0136523	.0358016	-0.38	0.704
Labour quantity	-.0570265	0000738	-0.36	0.720
Tractor	-.1762133	.0376572	4.68	0.000***
Fertilizer quantity	.0002732	.0000898	3.04	0.003***
Seed quantity	.0001415	.0004129	0.34	0.733

Pesticide quantity	-.018479	.0056054	- 3.30	0.002***
Herbicide quantity	-.0002231	.0003859	- 0.58	0.565
Cons	1.059472	.1204607		0.000

Source: Field survey(2018) *sig 10%, **sig 5%, ***sig1%

Table 5: Factors Affecting technical efficiency of marginal farm size farmers

Technical efficiency	Coefficient	Std. Err	T	P>|z|
Years of education	.0232586	.0037762	2.40	0.405
Farming experience	011868	.0012051	-2.15	0.180
Access to credit	-.0136523	.0358016	-0.38	0.241
Labour quantity	-.0570265	0000738	-0.36	0.720
Tractor	-.1762133	.0376572	4.68	0.509
Fertilizer quantity	.0002732	.0000898	3.04	0.241
Seed quantity	.0001415	.0004129	0.34	0.20
Pesticide quantity	-.018479	.0056054	- 3.30	0.009***
Herbicide quantity	-.0002231	.0003859	- 0.58	0.046**
Cons	1.059472	.1204607		0.000

Source: Field survey(2018) *sig 10%, **sig 5%, ***sig1%

Table 6: Factors affecting technical efficiency of small scale farmers

Technical efficiency	Coefficient	Std. Err	T	P>|z|
Years of education	.0232586	.0037762	2.40	0.007***
Farming experience	011868	.0012051	-2.15	0.314
Access to credit	-.0136523	.0358016	-0.38	0.241
Labour quantity	-.0570265	0000738	-0.36	0.942
Tractor	-.1762133	.0376572	4.68	0.002***
Fertilizer quantity	.0002732	.0000898	3.04	0.770
Seed quantity	.0001415	.0004129	1.1	0.599
Pesticide quantity	-.018479	.0056054	- 3.30	0.221
Herbicide quantity	-.0002231	.0003859	- 0.58	0.112
Cons	1.059472	.1204607		0.000

Source: Fieldsurvey(2018) *sig 10%, **sig 5%, ***sig1%

Table 7: Factors affecting technical efficiency of large scale farmers

Technical efficiency	Coefficient	Std. Err	T	P>|z|
Years of education	-.014586	.00595589	0.423	0.056*
Farming experience	-011868	.0021217	0.526	0.014**
Access to credit	-.0136523	.0465352	-6.03	0.423
Labour quantity	.0000465	0000693	3.70	0.526
Tractor	.2700133	.0448151	3.3	0.000***
Fertilizer quantity	.0003532	.0000948	3.70	0.001***
Seed quantity	.0001415	.000541	2.94	0.008***
Pesticide quantity	.0353656	.0057452	-6.16	0.000***
Herbicide quantity	-.0008135	.033859	-2.41	0.025**
Cons	1.423952	1.76607	8.15	0.000

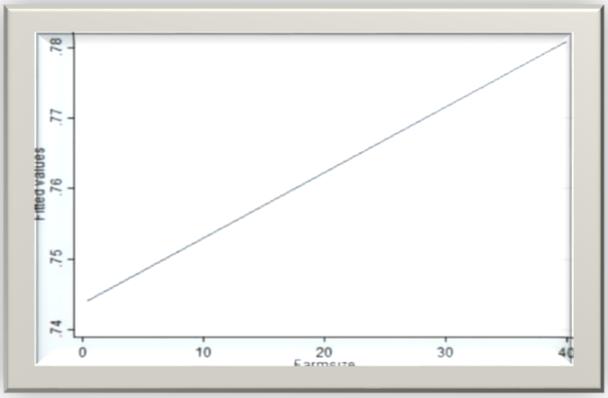
Source: Fieldsurvey(2018) *sig 10%, **sig 5%, ***sig1%

Table 8: Comparison of the determinant of the technical efficiency of farm size classes

Farmsize/ Determinants	Marginal farmsize	Small farm size	Medium & largefarm size	All the farmers
Years offormaleducation	Significant	Significant	Significant	Significant
Farming years'experience	Significant		Significant	Significant
Mechanization		Significant	Significant	Significant
Fertilizer quantity			Significant	Significant
Herbicide quantity			Significant	
Pesticide quantity	Significant		Significant	Significant
Seed quantity			Significant	
Access to credit				
Labor quantity				

Source: Field survey (2018)

Figure 1: Relationship between Farm size and Technical Efficiency



Source: Field survey (2018)

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