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Research Article

Analysis of Technical Efficiency on Orange Fleshed Sweet Potatoes Production Among the Smallholder Farmers in Migori County Kenya

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Abstract

Sweet potatoes (*Ipomea batatas* L.), particularly the orange fleshed variety, have become increasingly popular due to their ability to thrive in various environmental conditions with minimal inputs. Orange fleshed sweet potatoes (OFSPs) show potential for productivity, yet smallholder farmers in Kenya still struggle to maximize their yields. The factors influencing OFSP production efficiency among these farmers in Western Kenya have not been thoroughly examined. This study evaluated the technical efficiency of OFSP production among smallholder farmers in Migori County. Using a descriptive research design, a sample of 225 OFSP farmers was randomly selected by a cluster sampling technique. Data was collected through a structured questionnaire on inputs and selected socio-economic factors. The data was analyzed using the frontier stochastic model in STATA. Smallholder farmers estimated mean technical efficiency was 77.82% significant variables were; size of the land, availability of planting vines, access to hired labour, gender of the household decision maker, farming experience, household size, land ownership status, participation in training programs and extension services, and proximity to markets, indicating a need to improve OFSP production by 22.18%. These findings suggest that to reduce inefficiencies among smallholder OFSP farmers, targeted training programs are needed to enhance farmers' agronomic knowledge specific to OFSP production. Further, policy interventions should prioritize the provision of extension services to support and improve the performance of OFSP smallholder farmers.

Keywords

Technical Efficiency, Stochastic Frontier Model, Orange Fleshed Sweet Potato, Productivity, Smallholder Farmer

1. Introduction

Various varieties of sweet potatoes exist depending on flesh and skin colour. The most common types in Kenya are orange and deep purple sweet potatoes [29, 5, 16]. Orange fleshed sweet potato is a type that grows well in rain-fed systems and has a yield with a short growing season. Among all root crops, fleshed sweet potato is the most nutritious and profitable [29, 5]. Like other root crops, OFSPs have the potential to provide nutrition, food security and income for various households [20, 32]. They can be used to make food items at different stages of processing. People often consume them raw and

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prepare them by steaming, boiling, grilling, or processing them further [6].

The orange fleshed sweet potato has been biofortified to contain levels of beta carotene [20, 6]. Beta carotene is a pigment found in plants and foods, giving the orange colour to the orange fleshed sweet potato. Beta carotene is converted into Vitamin A by our bodies, which is of crucial benefit [33, 5]. Biofortification, achieved through plant breeding, agronomic techniques, or biotechnology, aims to increase the concentration of vitamins and minerals in food crops, thereby enhancing their nutritional value. Provitamin A Carotenoids, zinc, and iron are vitamins and minerals that can be increased through biofortification methods [18, 29].

Smallholder OFSP farmers have the ability and potential to produce up to 50 tonnes per hectare. However, these smallholder farmers only achieve a production level of around 14 tonnes per hectare [29, 20, 5]. This significant gap between the potential output can be attributed to factors such as production techniques, human factors, socio-economic and marketing, among other factors.

The regular tasks involved in managing OFSP production, such as planting, weeding, pest and disease control and harvesting, require farmers attention. If these efforts do not yield results, they may discourage farmers from continuing with the production of OFSP [13, 26, 25, 2]. To maximize their outputs and earnings, farmers must understand how efficiently they are integrating inputs such as recommended planting materials, labour, land and agrochemicals based on their production levels. According to [8, 5] socio-economic factors such as education, training, and sufficient financial resources can significantly impact technical efficiency. At the same time, supportive policies, developed infrastructure and easy market access also play vital roles. Depending on the prevailing conditions, these can also negatively impact the production of OFSPs.

Improving efficiency is crucial for increasing productivity in farming systems that often face limited resources and opportunities for innovation [25, 6]. [24, 8] further emphasized the need for resource utilization among farmers to achieve production targets effectively and maximize profits. Improving efficiency is particularly important as it can help enhance OFSP production and optimize resource management. Farm efficiency has garnered attention worldwide, holding significance at the microeconomic and macroeconomic levels. Improving the utilization of resources by farmers is crucial for increasing output, productivity, household income, food security, poverty alleviation and overall economic growth [36]. When an OFSP enterprise operates efficiently, it naturally attracts investment.

Despite the importance of farm efficiency, there is a research gap on the technical efficiency of OFSP production, specifically in Migori County. Orange fleshed sweet potatoes are a crop that can help combat vitamin A deficiency while providing employment opportunities for farming households and as a source of income. This study aimed to bridge this gap by analyzing the technical efficiency of smallholder OFSP producers in Migori County, Kenya.

2. Materials and Methods

2.1. Study Area

This study was carried out in April 2022 in Migori County, located in southwestern Kenya. Migori County is notably recognized as one of the key OFSP producers in Kenya's western region. A significant contributing factor to this accomplishment is Migori County's extensive size, covering a total area measuring 2613.5 km2. The study concentrated on Suna East and Kuria West Sub Counties. Sampling was conducted within four wards for Suna East: Suna Central, God Jope, Kakrao and Kwa Wards. In Kuria West, sampling procedures were executed within Tagare, Isebania, Bukira East and Bukira Central Wards in this sub-county. Weather patterns experienced within the region are bimodal rainfall distribution. During any given year, rainfall levels range from 700 mm to 2,200 mm. Agriculture, fishing and mining dominate among the socio-economic activities within the areas.

2.2. Data Collection and Procedure

The study utilized a cluster random sampling procedure to interview smallholder OFSP farmers from 6500 households' in Migori County. A sampling frame was used to divide the OFSP farmers within Suna East and Kuria West. A random sampling of OFSP smallholder farmers from the sample Wards was used to select a sample of 225 respondents derived using the Nassiuma formula of 2000 [28]. A semi-structured questionnaire was used to collect quantitative and qualitative data. Semi-structured questionnaire, was tested through a pilot study conducted in Kabondo East Ward, targeting smallholder OFSP farmers. The questionnaire was assessed for validity by experts and supervisors, ensuring readability and accuracy. Reliability was confirmed using the Cronbach Alpha test, with a coefficient of 0.74, indicating an acceptable level of consistency. The pilot study also helped identify potential challenges and refine the questionnaire for the actual study. The key informants of the study were OFSP farmers and officials from the State Department of Agriculture in Migori County. Data collected were on land, labour, OFSP planting materials, fertilizers, and agrochemicals as inputs. The inefficiency variables were access to bank credits, household size, land entitlement, market distance, market assurance, access to training, extension visits, group membership, digital credits, gender, education, and farming experience levels.

2.3. Analytical Framework

There are primarily three sources of variation in output: fluctuations in inputs, technical inefficiency, and random shocks. The contribution of inputs can be captured by using a production function specification. Computing the variation in output due to technical inefficiency and random shocks, the stochastic production frontier approach (parametric approach) can be employed. Inefficient production leads to inefficient use of scarce resources. Different approaches, such as stochastic production frontier and data envelopment analysis (DEA), also known as the nonparametric approach, can be used to estimate technical efficiency (T.E.). [9, 15, 11] discussed the advantages and disadvantages of each approach. However, it should be noted that the DEA approach assumes no random shocks in the data set. Since farmers always operate under uncertainty, this study analyzed a stochastic production frontier approach introduced by [4, 23]. By following their specification, the stochastic production frontier is written as follows;

$$Y = f(X_\alpha ; \beta)\mathcal{E} \tag{1}$$

The quantity of output of Orange Fleshed Sweet Potatoes (OFSP) is denoted as Y. It is determined by a vector of input quantities, Xα, and a vector of parameters, β. Additionally, there is a stochastic disturbance term, ε, which consists of two independent elements, u and v.

$$\mathcal{E} = U + V \tag{2}$$

V, which considers elements outside the farmer's control, such as environmental constraints and government policies. U is a symbol of technical inefficiency. Combining (1) and (2) gives the farm's frontier;

$$Y = f(X_\alpha ; \beta) * \mathcal{E}(U + V) \tag{3}$$

2.4. Empirical Model

Technical Efficiency denotes the ability of a farm's decision-making to efficiently produce the highest achievable output using prescribed inputs and technology. Empirically, this is outlined by specifying the stochastic frontier production function as shown below:

$$\ln Y_i = \beta_\circ \sum_{i=1}^{n} \beta_i \ln X_i + \mathcal{E}_i \tag{4}$$

$$\text{Ln}\, Y = \beta_\circ + \beta_1 \ln famlabourdays + \beta_2 hiredlabourdays + \beta_3 \ln Land + \beta_4 \ln planmtls + \beta_5 \ln plantfertb + \beta_6 \ln pmanqtyb + \beta_7 \ln agrochem + V_i - U \tag{5}$$

Where:

U = Captures inefficiency level caused by socio-economic factors that affect productivity, i, is the observation of the ith farmer, ln, the logarithm to base of e. Y represents the quantity of OFSP produced, plantfertb, is the quantity of fertilizers, pmanqtyb, is the quantity of manure, planmtls, is the quantity of planting materials, and agrochem, is the quantity of other agrochemicals other than fertilizers used.

$$Ui = \delta_\circ + \delta_1\text{gender} + \delta_2\text{yrsofsp} + \delta_3\text{yrsedu} + \delta_4\text{hhsize} + \delta_5\text{landtit} + \delta_6\text{Mrktdist} + \delta_7\text{mktassurance} + \delta_8\text{acctrainm} + \delta_9\text{groupfun} + \delta_{10}\text{credtofsp} + \delta_{11}\text{conextveg} + \delta_{12}\text{digiace} + \omega \tag{6}$$

Where:

ωi, = Represent random normally distributed error term

Ui, = Technical inefficiency of the ith farmer

yrsofsp = The years of farming experience,

hhsize= The household size,

landtit = access to the land title deed,

mrktdist = Distance to the OFSP market in Kilometer,

mktassurance = Assurance of the OFSP market,

acctrainm = Access to training on OFSP production and marketing,

groupfun = Group membership,

credtofsp = Access to bank credits,

conextveg = Number of extensions visits yearly,

digiace = Access to digital finances for OFSP production.

3. Results and Discussion

3.1. Descriptive Statistics

Table 1 shows the summary of the variables used in the study. The socio-economic variables were gender, land ownership, access to OFSP production training, group membership, bank credits and digital financing. On average, the smallholder farmers had 10.5 years of OFSP farming and production experience. Additionally, these farmers attained nine years of education and a household size of eight (8) members. The smallholder farmer had an average of one (1) contact visit to acquire extension service and the average distance to the nearest urban market was 15.46 kilometers.

Table 1. *Descriptive Statistics for the Variables Used in the Study.*

Variable	Observation	Mean	Std. Dev.	Minimum	Maximum
Log Y(Output)	225	3.039	0.741	1.386	5.011
Log Land	225	0.077	0.650	-1.386	1.609
Log Other Agrochemicals	225	0.226	0.712	0.000	3.401

Variable	Observation	Mean	Std. Dev.	Minimum	Maximum
Log Planting materials	225	7.735	1.129	4.344	9.210
Log planting fertilizer	225	0.321	1.361	0.000	7.313
Log Manure	225	1.326	1.525	0.000	8.006
Log Family labour	225	2.824	0.881	0.000	4.290
Log Hired labour	225	1.710	1.204	0.000	4.263
Farming decision-maker's Gender	225	0.787	0.411	0.000	1.000
Years of farming experience	225	10.502	5.526	0.000	30.000
Years of education	225	9.213	2.874	0.000	18.000
Household size	225	7.396	2.828	2.000	21.000
Land title deed	225	0.489	0.501	0.000	1.000
Market distance	225	15.462	9.263	2.000	32.000
Market assurance	225	0.120	0.326	0.000	1.000
Access to training	225	0.271	0.446	0.000	1.000
Group membership	225	0.244	0.431	0.000	1.000
Access to bank credit	225	0.058	0.234	0.000	1.000
Contacts for extension service	225	0.938	1.259	0.000	8.000
Access digital finance	225	0.151	0.359	0.000	1.000

3.2. Stochastic Frontier Model

The study utilized a two-step method to derive maximum likelihood estimates with the assistance of STATA version 15. The frontier and inefficiency model parameters were computed simultaneously using the stochastic frontier model to ensure estimations. The first step was to check for multicollinearity between the continuous and categorical explanatory variables using the variance inflation factor (VIF) and contingency coefficient (CC). Just like [1] the values of the VIF and CC for every variable included in this model were below 10 and 0.75, respectively, indicating no substantial problem with multicollinearity among the explanatory variables.

Then, the assumption of the stochastic frontier technique was confirmed: the assumption that Cobb Douglass is rigid while Translog is flexible. The likelihood ratio test determined the functional form between the Translog and Cobb Douglas production functions [20, 21]. To choose between these two forms for the data, a null hypothesis (H0), stating that not all interaction and square terms are more significant than zero and an alternative hypothesis (H1), stating that the coefficients are greater than zero, were set. In this case, the assumption was met, indicating that the coefficients are greater than zero.

Lastly, examining the inefficiency once the appropriate production function is established is also essential. The null hypothesis suggested that smallholder farmers of OFSP had no room for improvement in terms of efficiency (H0=Y=0). On the contrary, the alternative hypothesis suggested that these farmers were inefficient (H1=Y>0). The gamma parameter, Y=du2/ (du2+ dv2), ranges from 0 to 1. When gamma equals zero, the difference between farmer productivity and maximum projected production can be attributed to errors. However, if the value approaches one, inefficiency significantly affects the production system [22, 10]. The study did not accept the hypothesis as the gamma value exceeded zero (0.0034>0). Consequently, inefficiency in production was evident in the OFSP production in Migori County.

3.2.1. Computing the Level of Technical Efficiency

Based on the mean technical efficiency of OFSP production derived from the smallholder farmers in Migori County in Table 2. There is room to improve the output of OFSP by 22.18%, given a specific level of input application. The least and most efficient farmers operated on levels 35.53% and 99.94%, respectively. The result is consistent with [31], 76% level of technical efficiency on OFSP root production in Nigeria.

Table 2. Average Level of Technical Efficiency.

Variable	Observation	Mean	Std. Dev.	Minimum	Maximum
Technical Efficiency	225	0.778	0.192	0.355	0.999

The main objective of the study was to analyze the technical efficiency of farmers growing orange sweet potatoes (OFSP) in Migori County and identify the factors influencing their efficiency levels. OFSP ensures food security and serves as a cash crop in Kenya in Migori County. During the study, it was observed that a considerable number of smallholder farmers exhibited efficiency in their production of OFSP. It was noted that most farmers operated at or above (70%) efficiency, while 40.89% of the sampled households had an efficiency level below 70% yet were still considered relatively efficient on average, as shown in Table 3. This indicates room for improvement for those operating below efficiency levels, either by increasing their productivity or reducing input costs while maintaining the production level. To achieve this, policy strategies should promote efficient utilization of existing inputs and technologies and provide support and resources to enhance farmers' capacity to utilize these inputs efficiently. Table 4 shows the average quantity of OFSP harvested at each level of technical efficiency.

Table 3. Distribution of Technical Efficiency Level.

Technical efficiency Distribution	Frequency	Percentage
0.300	1.000	0.440
0.400	14.000	6.220
0.500	42.000	18.670
0.600	35.000	15.560
0.700	27.000	12.000
0.800	17.000	7.560
0.900	89.000	39.560
Total	225	100.000

Table 4. Level of Technical efficiency and quantity harvested.

Technical efficiency Distribution	Mean (Quantity Harvested)
0.300	6.000
0.400	14.214
0.500	13.595
0.600	19.200
0.700	19.352
0.800	24.941
0.900	42.944

3.2.2. Inputs and Inefficiency Factors on Technical Efficiency

Table 5 shows the stochastic frontier model output. The study focused on seven input variables; land size, agrochemicals usage, access to planting materials, inorganic fertilizer, manure, family, and hired labour days. The inefficiency variables in the study were the gender of the decision maker, years of OFSP farming experience, years of education, household size, land ownership, distance to the market, market assurance, access to training, access to credit, access to digital financing, extension service and group membership. The outputs were either positive or negative at 10%, 5% and 1% significance levels. The findings highlighted factors that impact efficiency among these smallholder farmers; it was observed that various factors significantly influenced the outcome of OFSP farming. These include the size of the land, availability of planting vines, access to hired labour, gender of the household decision maker, farming experience, household size, land ownership status, participation in training programs and extension services, and proximity to markets.

Land size had a positive coefficient and was significant at a 1% significance level on technical efficiency. Production would be increased by 0.4805 for every unit increase in an acre of land allotted to OFSP farming. This suggests that production will most likely increase if farmers increase the land area under OFSP. [30, 12, 7] findings regarding the importance and beneficial effect of land area maize, wheat and coffee production output were consistent with the current study on OFSP production in Migori County.

The planting material for OFSP production was significant in this study, showing a positive coefficient at a 10% significance level. This implies that by increasing the use of certified vines, there is a 0.0654-fold increase in OFSP production. The availability of planting vines impacted the efficiency of farmers growing OFSP. By making planting vines readily available, it becomes easier to propagate potatoes, maintain purity, prevent diseases and promote faster growth. This may lead to yields of OFSP contributing to food security and sustainable agriculture. The use of hired labour also plays a role in enhancing OFSP production. More labour days are employed in the production process, improving planting, harvesting and post-harvest activities efficiency. As a result, this leads to yields and better crop management. This aligns with the findings of [3], who reported that utilizing certified seeds of improved cassava varieties in Uganda led to improved productivity and household welfare. Using clean vines enhances the performance of OFSPs, consequently improving overall yield.

Hired labour positively impacted technical efficiency at a 5% significance level. Increased hired labour days would result in a 0.074 increase in the OFSP produced. Hired labour in OFSP production positively impacts technical efficiency by enabling specialized tasks, timely operations, and efficient resource utilization. Skilled labour can enhance crop management practices, such as planting and harvesting, resulting in optimal yields and reduced wastage. This expertise contributes to improved overall efficiency in OFSP cultivation. These findings align with research by [35] who also found a relationship between labour input and maize production in the Banten province.

The gender of individuals making household decisions played a role in negatively impacting technical efficiency at a 1% significance level. The implication of negative correlation means female-headed households had better opportunities for increasing efficiency than male household heads. Male decision-makers did not allocate land for cultivating orange-fleshed potatoes (OFSP). Despite their strength compared to female farmers, they display an unfavorable attitude towards OFSP production. Interestingly, fleshed sweet potato cultivation is predominantly associated with female farmers in Kenya and several other sub-Saharan African countries [10, 17, 34]. Likewise, land ownership had a negative relationship with efficiency at a 10% significance level. Access to the land title by the female-headed households improved efficiency. This finding is similar to the findings of [24] who reported that female-headed households were more efficient in producing Irish potatoes in Cameroon.

The statistical analysis showed a negative coefficient of farming experience on inefficiency levels at a 1% significance level. Each unit increase in experience results in 0.0283 factors decrease in inefficiency. The more experienced a farmer is, the greater their technical efficiency. Farmers with experience and larger households tend to be more efficient in their operations. This suggests that experienced farmers with more household members are likely to acquire labour for their OFSP farms, which increases efficiency over time. Additionally, farming experience often leads to improved skills. This finding agreed with the study by [14, 19] who reported a positive relationship between farming experience and farm productivity in utilizing and adopting Zai pits in drier upper Eastern Kenya.

The household size decreased inefficiency at a 5% significance level. This implied a positive impact on the efficiency level of the smallholder farmers. Specifically, for every unit increase in household size, the technical inefficiency of production decreased by 0.0302 units, leading to an improvement in efficiency. This can be attributed to the fact that larger households tend to have available cheap labour for use in OFSP production, which enhances efficiency and productivity. The research funding was inconsistent with the report by [31], who reported that household size plays a crucial role in the technical efficiency of OFSP root production in North Central Nigeria. However, relying on family labour on small farms may lead to underutilizing labour resources [22].

The positive correlation between market distance and inefficiency at a 1% significance level suggests that the longer the distance to markets, the lower the efficiency of producing OFSP. From the result, a unit increase in the distance to urban markets causes a 0.0111-factor increase in technical inefficiency affecting OFSP production. The positive correlation between market distance and inefficiency suggests that the distance to markets lowers the efficiency of producing OFSP. When the distance to the market is long, it negatively impacts OFSP production by increasing transportation costs and causing delays in reaching consumers. This can result in spoilage, reduced profits, and less motivation for farmers to cultivate OFSP. These findings align with a study by [30, 21]. Consequently, farmers tend to cultivate crops on plots of land due to proximity to viable markets.

Another aspect that impacted technical efficiency was the availability of training opportunities. The negative coefficient for access to training at 1% significance indicates a positive influence on technical efficiency. This suggests that when smallholder farmers have access to training on OFSP production, it reduces inefficiency by 0.3173 factors. Smallholder farmers who receive training tend to demonstrate efficiency in their farming practices. Training and knowledge acquisition is crucial to overcoming farmers' production constraints and enhancing efficiency. By acquiring knowledge, farmers can alleviate constraints. Ensure timely acquisition and utilization of inputs, ultimately leading to improved efficiency. Therefore, it is recommended that the government directly connect farmers with training institutions such as workshops and expositions. Additionally, farmers can utilize informal channels as a source of knowledge to promote production. The result was inconsistent with [21] which addressed the issue of narrowing yield gaps in smallholder farming and its implications for achieving a living income. The study's findings suggest that despite efforts to improve crop yields and productivity through training, simply closing the yield gaps does not necessarily lead to a guaranteed living income for smallholder farmers in the region.

The coefficient of the number of visits to extension services was negative, indicating a positive effect on the level of technical efficiency in OFSP production at a 10% significance level. When smallholder farmers visited to seek extension services, inefficiency was reduced by 0.0843 factors. Farm households with contact with extension workers tend to be more efficient. Hence, substantial productivity gains can be achieved by enhancing the production efficiency of smallholder OFSP producers. These findings align with a study conducted by [27], which showed that tomato farmers in Kirinyaga County, Kenya, greatly benefited from extension services and demonstrated efficiency.

Table 5. *Stochastic Frontier Model Estimates on OFSP technical efficiency in Migori County*.

logY	***Coefficient***	***standard error*.**	**P>*z- Z-statistics***
Frontier			
Log of Land	0.481***	0.070	0.000
Log of Agrochemicals	0.057	0.047	0.230
Log of Planting vines	0.065*	0.036	0.072
Log of Fertilizers	0.037	0.026	0.147
Log of Manure	0.014	0.020	0.497
Log of Family labour days	0.012	0.038	0.757
Log of Hired labour days	0.074**	0.036	0.038
_cons	2.574	0.315	0.000
Inefficiency			
Gender	0.268***	0.090	0.003
Years of farming experience	-0.028***	0.007	0.000
Years of schooling	0.003	0.014	0.805
Household size	-0.030**	0.014	0.032
Land title deed	0.116*	0.070	0.099
Market distance	0.011***	0.004	0.002
Market assurance	0.145	0.104	0.161
Access to training	-0.317***	0.121	0.009
Group membership	-0.085	0.110	0.441
Credit access	0.024	0.210	0.909
Extension service contacts	-0.084*	0.050	0.093
Access to digital finance	-0.042	0.131	0.749
_cons	0.426	0.169	0.012

***, **, * Represents levels of significance at 1%, 5% and 10% respectively.

4. Conclusions and Recommendations

The study assessed the technical efficiency of smallholder Orange-Fleshed Sweet Potato (OFSP) farmers in Migori County, Kenya, identifying key factors influencing their efficiency. The findings revealed that smallholder farmers exhibited varying levels of efficiency, with room for improvement particularly in land utilization, planting material quality, and labor management. Factors such as land size, access to certified planting vines, hired labor, gender of household decision-makers, farming experience, household size, market distance, access to training, and extension services significantly impacted efficiency. The study highlighted the potential for efficiency gains through better resource management and targeted support. To enhance OFSP production efficiency, smallholder farmers should focus on optimizing land use by expanding cultivation areas and adopting certified planting vines to improve yields. Strengthening access to quality training and extension services is crucial for improving farming practices and overcoming production constraints. Encouraging the participation of female-headed households in

OFSP farming and facilitating access to markets can also boost efficiency. Lastly, reducing the distance to markets through improved infrastructure or establishing closer collection points can mitigate inefficiencies related to transportation costs and delays. These targeted actions can help farmers increase productivity, reduce costs, and enhance overall profitability.

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Author Contributions

Lawrence Otieno Jabuya: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing

Shelmith Wanja Munyiri: Conceptualization, Investigation, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing

Martin Kagiki Njogu: Conceptualization, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing

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Conflicts of Interest

The authors declare no conflicts of interest.

Appendix

. vif

Variable	VIF	1/VIF
logLand	3.12	0.320332
logHiredla~s	2.82	0.354479
logPlanmterl	2.55	0.391861
acctrainm	2.44	0.409958
conextveg	2.26	0.442956
logFamlabo~s	2.09	0.479030
groupfun	2.05	0.487183
digiace	1.91	0.523658
yrsedu	1.90	0.527001
logplantfe~b	1.80	0.556906
logAgrochem	1.72	0.582607
hhsize	1.71	0.584626
credtofsp	1.48	0.674625
logpmanqtyb	1.44	0.693889
landtit	1.40	0.712932
yrsofsp	1.31	0.765959
Mrktdist	1.29	0.774695
gender	1.23	0.815458
mktassurance	1.22	0.821341
Mean VIF	1.88	

Figure 1. *Multicollinearity check.*

```
Iteration 0:   log likelihood = -145.66022

Generalized linear models                       No. of obs      =        225
Optimization     : ML                           Residual df     =        217
                                                Scale parameter =   .2215922
Deviance         =   48.0855079                 (1/df) Deviance =   .2215922
Pearson          =   48.0855079                 (1/df) Pearson  =   .2215922

Variance function: V(u) = 1                     [Gaussian]
Link function    : g(u) = u                     [Identity]

                                                AIC             =   1.365869
Log likelihood   = -145.6602193                 BIC             =  -1127.208
```

logY	Coef.	OIM Std. Err.	z	P>|z|	[95% Conf.	Interval]
logLand	.5361946	.0805516	6.66	0.000	.3783165	.6940728
logAgrochem	.1299551	.054057	2.40	0.016	.0240053	.2359048
logPlanmterl	.09686	.0419768	2.31	0.021	.0145869	.179133
logplantfertb	.0404057	.0298683	1.35	0.176	-.0181351	.0989464
logpmanqtyb	.0223191	.0232926	0.96	0.338	-.0233335	.0679717
logFamlabourdays	.0362884	.0431208	0.84	0.400	-.0482268	.1208037
logHiredlabourdays	.0875639	.0411817	2.13	0.033	.0068492	.1682785
_cons	1.924561	.3513364	5.48	0.000	1.235954	2.613168

Figure 2. *Likelihood Ratio Test.*

```
Stoc. frontier normal/tnormal model              Number of obs =        225
                                                 Wald chi2(7)  =     251.24
                                                 Prob > chi2   =     0.0000

Log likelihood =  -110.4742
```

logY	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Frontier						
logLand	.480505	.069699	6.89	0.000	.3438974	.6171125
logAgrochem	.0564604	.047046	1.20	0.230	-.0357481	.1486688
logPlanmterl	.0654176	.0363119	1.80	0.072	-.0057525	.1365876
logplantfertb	.037432	.0258153	1.45	0.147	-.0131651	.0880291
logpmanqtyb	.0138549	.020414	0.68	0.497	-.0261559	.0538656
logFamlabourdays	.0119058	.0384367	0.31	0.757	-.0634287	.0872403
logHiredlabourdays	.0739792	.0356821	2.07	0.038	.0040436	.1439149
_cons	2.573986	.3152597	8.16	0.000	1.956089	3.191884
Mu						
gender	.2682867	.0902496	2.97	0.003	.0914006	.4451727
yrsofsp	-.0283362	.0067452	-4.20	0.000	-.0415564	-.0151159
yrsedu	.0033565	.0136238	0.25	0.805	-.0233457	.0300586
hhsize	-.0302234	.0141223	-2.14	0.032	-.0579027	-.0025442
landtit	.1156257	.0701359	1.65	0.099	-.021838	.2530895
Mrktdist	.0110614	.0034987	3.16	0.002	.004204	.0179188
mktassurance	.1452701	.1036296	1.40	0.161	-.0578403	.3483805
acctrainm	-.3173135	.1214396	-2.61	0.009	-.5553308	-.0792963
groupfun	-.0849926	.1102632	-0.77	0.441	-.3011044	.1311192
credtofsp	.0241068	.2103279	0.11	0.909	-.3881282	.4363418
conextveg	-.0843336	.05019	-1.68	0.093	-.1827042	.0140369
digiace	-.0418233	.1305023	-0.32	0.749	-.2976032	.2139565
_cons	.4254665	.1689482	2.52	0.012	.0943341	.756599

Usigma						
_cons	-7.526785	4.117951	-1.83	0.068	-15.59782	.5442503
Vsigma						
_cons	-1.852109	.0949982	-19.50	0.000	-2.038302	-1.665915
sigma_u	.0232049	.0477783	0.49	0.627	.0004102	1.312751
sigma_v	.3961136	.018815	21.05	0.000	.3609013	.4347615
lambda	.0585814	.0523542	1.12	0.263	-.0440309	.1611937

Figure 3. *SFM STATA Output.*

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