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Full Length Research

Technical Efficiency Analysis of Cassava Production in Nigeria; Implication for Increased Productivity and Competitiveness

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Despite the fact that Nigeria is the largest producer of cassava in the whole world, production lags behind the increasing local demand for food and industrial usage, and cassava products are not price competitive in the global market. This paper uses stochastic production frontier approach to examine resource use efficiency of cassava farmers in order to provide empirical guide to competitive cassava production in Nigeria. Production function exhibits constant return to scale and technical efficiency can be improved by as much as 10 percent. Policy suggestions for technical change and outward shift in production function for competitive cassava production are provided.

Key words: Technical efficiency, Stochastic frontier production function, Cassava farming, Nigeria.

INTRODUCTION

Cassava (*Manihot esculenta*) was introduced into Africa from Brazil by Portuguese traders in the 16th century (Akoroda and Ikpi, 1988). Although the tuber crop was initially adopted as famine-reserve crop due to its suitability for food during the lean seasons, it has become a main food staple amongst rural and urban households across Africa (Nweke, 1994). Cassava gives a carbohydrate production which is about 40 percent higher than rice and 25 percent higher than maize, making it a suitable raw material for industrial production of ethanol, starch, adhesives, bio-fuels, glucose syrup among others (Tonukari, 2004). According to FAOSTAT, Nigeria has been the largest producer of cassava in the whole world for more than a decade. The growing importance of cassava as a major food and cash crop in the country has put it on the priority list of government and the international development agencies as a target crop for food security and potentials for agro-based industrialization. For example, the Nigerian government has legislated the inclusion of minimum of 5% cassava flour in bread and confectionaries as substitute for imported wheat flour due to similarity in their physicochemical properties. However, cassava production in Nigeria is largely driven by continuous land expansion rather than increased productivity per unit land (yield). While production quantity and area harvested have increased substantially over the years, productivity (yield) only shows a marginal increase (Figure 1).

Compared to other major producing countries like Brazil, Thailand and Indonesia, Nigeria's yield is ranked lowest. Given the increasing industrial demand for cassava and a soaring population whose main staple is the crop, production no longer cope with the local demand while the processed products such as starch and chips are not price competitive in the global markets (Westby, 2010). According to IITA (2007), high cost of production and processing are the key constraints to competitive production and commercialization of cassava in Nigeria, however these can be attributed to low productivity.

Raising productivity per unit land and labour through efficient use of production resources is a sure way of reducing per unit cost of production and ensuring

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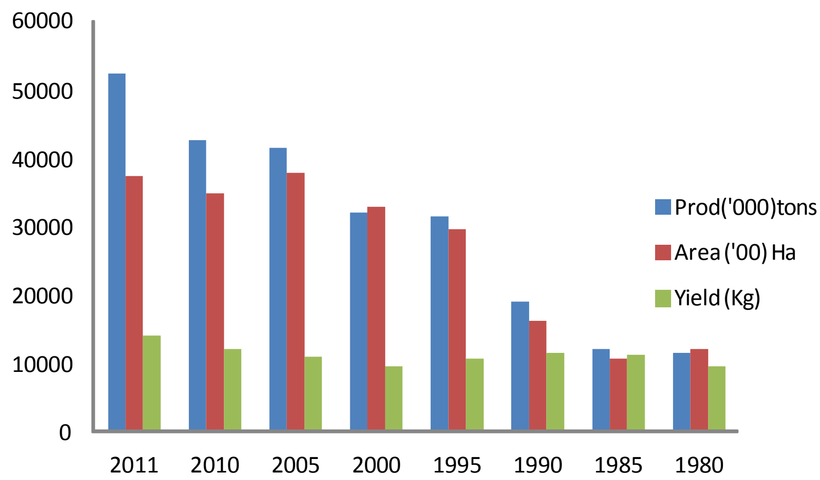

Figure 1. Quantity of cassava produced, area harvested and yield from 1980 - 2011
Source: FAOSTAT.

competitive production. A number of studies have analyzed resource use efficiency of smallholder farmers in Nigeria using the production function approach (e.g Raphael, 2008; Omonona *et al*., 2010; Asogwa *et al*., 2011; Audu *et al*., 2013). The present study contributes to the debate by employing transcendental logarithm production (Translog), which is statistically superior to models with first order approximation such as Cobb-Douglas and Ordinary Least Square Regression approach used by the previous studies. Translog production function offers second order flexible forms which allow input substitution to be unrestrictive. Its second order approximation is important in explaining squares and interaction of inputs, as well as elasticities of substitution between inputs (Debertin, 1986). We also provide policy suggestions for technical change and outward shift in the production function of smallholder producers based on findings from this research. The induced agricultural development model proposes a mechanism whereby a society chooses an optimum path for technological change based on her resource endowment and opportunities. The induced agricultural development model proposes a mechanism whereby a society chooses an optimum path for technological change based on her resource endowment and opportunities (Ruttan and Haymi 1972). For instance, Ebukiba (2010) noted that labour accounts for the highest share of the cost of cassava production in Nigeria due to its continuous movement to other sectors of the economy. In developed countries, the constraints imposed by inelastic supply of labour have been successfully offset by substitution with mechanized power, however mechanization is not within the reach of resource-poor farmers. In the spirit of the induced agricultural development model, the present study proposes feasible "labour-saving" and "land-saving" technologies within the context of smallholder agriculture being practised in Nigeria

MATERIAL AND METHODS

Theoretical Framework

A production function describes the technical relationship that transforms inputs (resources) into outputs (commodities) at a given level of technology (Debertin, 1986). The analysis of the efficiency of a production unit dates back to the scholarly work of Koopmans (1951) in which efficiency was defined as the relationship between input-use and output, and use of coefficients of resource utilization as measurement of efficiency. However, Farrel (1957) explained that efficiency of a production firm consists of technical, allocative and economic components. Technical efficiency is the ability to produce a given level of output with a minimum quantity of inputs under certain technology; allocative efficiency refers to the ability to choose optimum input levels for given factor prices while, economic or total efficiency is the product of both technical and allocative efficiencies. However, Aigner *et al*. (1977) and Meeusen and Van den Broeck (1977) independently proposed the stochastic frontier production function approach which measures efficiency of a firm with reference to production frontier representing maximum output that is technologically feasible for a given set of inputs and a benchmark of optimum production. The model is characterized by error term comprising two components; the stochastic component (V_i) and the inefficiency of the producer (U_i). While the stochastic error term represents random shocks such as adverse weather and other factors beyond the control of a producer, the inefficiency component constitute a deviation from the production frontier as a result of the producer's inefficiency. Battese and Coelli (1995) extended the stochastic production frontier model by suggesting that the inefficiency effects can be expressed as a linear function of the explanatory variables, reflecting individual producer's characteristics. The advantage of this model is that it allows estimation of the farm-specific efficiency scores and the factors explaining efficiency differentials among farmers in a single stage estimation procedure. Assuming that the production function of the cassava producers in the study area is given by

$$Y_i = f(X_i, \beta) + V_i - U_i \qquad (1)$$

Where Y_i is cassava output for ith farmer; X_i represents the physical inputs, βs are the parameter estimates to be estimated; V_i is the stochastic error term that is assumed to be normally, independently and identically distributed (idd), with zero mean and unknown variance (σ^2_v), while U_i is the inefficiency component of the error term. A producer is efficient if he or she operates on the frontier, that is, the optimum output that could be realized from a given set of inputs. A producer who fails to produce on the frontier is therefore inefficient. Technical efficiency (TE) measures the ratio of an observed output to the optimum output that could be produced by a fully-efficient farmer using the same inputs vector. As expressed by Coeli *et al*. (2005), output oriented technical efficiency can be represented by

$$TE = \frac{Yi}{Ymax} = \frac{exp(Xi\beta + vi - ui)}{exp(Xi\beta + vi)} = exp(-ui) \qquad (2)$$

Technical efficiency takes a value between zero and one.

The Study Area and Sampling Procedure

The study was carried out in Southwest Nigeria, comprising of 6 out of the 36 States in the country. The region lies between longitude 2° 31' and 6° 00' East and latitude 6° 21' and 8° 37' North with a total land area of 77,818 km^2 and population of about 30 million people (National Population Commission, 2006). The region is predominantly inhabited by the *Yorubas* who mainly leave in the rural areas and have farming as their major occupation. Data were gathered with the aid of structured questionnaire and trained enumerators between August and October 2012. Information was collected on socio-economic characteristics as well as production activities of cassava producers for 2010/2011 farming session using multistage sampling procedure. Two States with prominence in cassava production and two local government areas in each of these States were purposively selected, based on information made available by the State's Agricultural Development Program office. This was followed by random selection of 5 communities in each of the 4 local government areas. Finally, 180 farmers were randomly selected in proportion to the population of the cassava farmers at the community level. However, only 160 questionnaires contained complete information and were therefore used for the study.

Empirical Model Specification

We employed transcendental logarithm production function (Christensen *et al*., 1971) to estimate the production parameters. The model is implicitly specified as follows

$$LnYi = \beta o + \sum_{n=1}^{5} \beta n \ln Xn + \frac{1}{2}\sum_{n=1}^{5} \sum_{m=1}^{5} \beta nm \ln Xn \ lnXm \qquad (3)$$

Where
Y = Output (tons)
X1 = Labour (mandays)
X2 = Stems (in bundles)
X3 = Herbicides (Liters)
X4 = Fertilizer (Kg)
X5 = Land (Ha)
V_i and U_i are assumed to be independently distributed of each other and uncorrelated with *Xi,* while U_i follows half normal distribution. Factors explaining the farmer's inefficiency are implicitly expressed as

$$\mu i = \delta o + \sum_{n=1}^{8} \delta n \, Zn \qquad (4)$$

Where
Z1 = Age (years)
Z2 = Age squared (years)
Z3 = Education (years)
Z4 = Gender: 1 if farmer is male, 0 otherwise
Z5 = Fertilizer usage: 1 if farmer uses fertilizer, 0 otherwise
Z6 = Herbicide usage; 1 if farmer uses herbicides, 0 otherwise
Z7 = Membership of farmers' association: 1 if farmer is a member, 0 otherwise
Z8 = Access to extension services: 1 if farmer has access, 0 otherwise

RESULTS AND DISCUSSION

Table 1 presents summary statistics of the production variables and socioeconomic characteristics of the respondents. The average age of the respondents is found to be about 52 years implying that the respondents are in their productive ages. Farmers are relatively educated with the majority having at least primary school education. Education is expected to reduce technical

Table 1. Summary statistics of inputs, output and socioeconomic characteristics of farmers.

Variable	Mean	Std dev	Minimum	Maximum
Age of farmers (years)	51.59	9.05	36	78
Education (years)	6.23	5.12	0	18
Gender (1= male, 0=female)	0.78	0.42	0	1
Farm Size (Ha)	2.36	1.31	0.45	8
Yield (tons/ha)	18.14	3.81	2.92	28
Number of cassava bundles planted	118	69.62	36	480
Output (tons)	43.12	26.16	3.5	121.44
Variety planted (1=local, 0=Improved)	0.26	0.44	0	1
Access to extension (1=yes, 0=no)	0.65	0.48	0	1
Labour used (Mandays)	108.19	66.17	17	427
Use of fertilizer (1=used, 0=not used)	0.12	0.13	0	1
Use of herbicides (1=used, 0=not used)	0.25	0.31	0	1
Fertilizer used (Kg/hectare)	25.96			
Herbicide used (Liters/hectare)	5.012			

Data source: Field survey, 2012

inefficiency as educated farmers would find it easier to understand information about production technologies and farming practices. 26 percent of the respondents cultivated local cassava varieties while 74 percent cultivated improved varieties, although some farmers cultivate both local varieties and improved varieties. Reasons given for cultivating local varieties include good storability in the soil for longer period of time after maturity, whereas the improved varieties store less, but rather begin to decay soon after maturity.

The widespread adoption of improved cassava varieties in the study area can be attributed to various governmental and non-governmental initiatives promoting commercialization of cassava in Nigeria. The notable ones include the "*Presidential Initiative for Cassava"* implemented by the Nigerian government (2002 – 2007), the "*Integrated Cassava Project"* of the International Institute of Tropical Agriculture (IITA) (2003 – 2010) and the "*Cassava Plus Project"* of the International Fertilizer Development Center (IFDC) (2009 – date). It is also amazing that 65 percent of the respondents had access to extensions services either from the State's Agricultural Development Program (ADP), or non-governmental organizations. Access to extension services is expected to reduce technical inefficiency because farmers are able to acquire information on best farming practices through participation in capacity building programs. Cassava yield in the study area is found to be 18.14 tons per hectare. Although this is higher than the current national average yield of 14.02 tons per hectare reported by FAOSTAT nevertheless, there are claims that there are improved cassava varieties that can produce as much as 40 tons per hectare, if standard agronomic practices are followed (IITA, 2010).

Only 12 percent of the respondents used fertilizer while the average per hectare usage of fertilizer is estimated to be 25.96kg/Ha. Although fertilizer is meant to be applied on the basis of soil analysis results, land history and vegetation can be a useful guide when this is not done. Lands naturally inundated with *Chromolaena odorata* (*Akintola taku*) as weed can support a good cassava crop without fertilizer, while the presence of spear grass or poorly established vegetation is a signal for a need for fertilization. In the latter case, farmers may need to apply up to 400kg of suitable fertilizer per hectare (IITA, 2004). Unfortunately, farmers decry exorbitant prices of chemical fertilizer and lack of access to the government's subsidized fertilizer. Weed is a major pest undermining cassava productivity as it competes with the crop for light, moisture and nutrients. It also harbours diseases and other pests, physically injures cassava plants and its storage roots. Manual weeding as a control measure is expensive due to labour scarcity, farmers are therefore encouraged to apply pesticides within the officially recommended limits however, farmers in the study area had limited knowledge of herbicides usage. Although 25 percent of the farmers indicated that they used herbicides for weed control in addition to the use of traditional tillage implements such as cutlass and hoes, the average per hectare use of herbicide is found to be 5.02 liters/Ha.

The maximum likelihood estimates of the production function parameters are reported in Table 2. The null hypothesis that there are no inefficiency effects is rejected at 1% level of significance. If the null hypothesis is true, then the stochastic frontier model reduces to an OLS model with normal errors. Likewise, gamma (γ) is estimated to be 0.857 and it is statistically significant at 1%, indicating that about 86% of the total variation in cassava output is due to technical inefficiency. The Likelihood ratio test for model specification is in favour of the translog model (Table 2). The production function is well behaved, with estimates of the standard deviations

Table 2. Likelihood ratio test.

Null hypothesis	LR Statistics	Critical Value (1%)	Decision
H_0: $\gamma = 0$ (No stochastic frontier)	59.73	28.517	Reject H_0
H_0: $\beta_6 = \beta_7 \ldots\ldots \beta_{20} = 0$ Cobb-Douglass specification	50.625	21.306	Reject H_0
H_0: $\delta 1 = \delta 1 \ldots\ldots\ldots \delta 1 = 0$ No technical inefficiency	15.42	10.725	Reject H_0

of the two error components (σ_v) and (σ_u), and the overall variance ($\sigma^2 = \sigma_v^2 + \sigma_u^2$) all statistically significant at 1 percent. Equally, most assumptions of a standard production function are satisfied, for example, the assumptions of monitocity are satisfied as all the marginal products are non-negative. These imply that the econometric models are quite appropriate. The continuous input variables in the production function are mean corrected so that the estimated coefficients of the first-order term can be interpreted directly as output elasticities at sample mean (Friedleander and Spady, 1980). Thus, parameter estimates are interpreted as follows; a 1 percent increase in labour leads to 15 percent increase in cassava output. Similarly, farm size, herbicides and labour exhibit positive and significant output elasticities, while the summation of output's elasticities to inputs show that cassava production is in the second stage of production, i.e constant return to scale. With respect to squares and interaction of inputs, empirical results reveal that increased use of fertilizer, herbicides and land will increase cassava output (Table 3).

Finally, the predicted technical efficiency scores range from 0.42 to 0.97 percent with an average score of 0.904. This shows that there is room for improvement and technical efficiency can be improved by about 10 percent. However, more than 80 percent of the farmers have technical efficiency scores greater than 0.7, which is a strong indication that majority of the farmers are quite efficient at the present level of technology. It thus intuitively implies that beyond this point, production function at the present level of technology may start to exhibit a decreasing return to scale. The distribution of technical efficiency scores are shown in Figure 2.

The maximum likelihood estimates of the determinants of inefficiency are shown in Table 4. The coefficients of age, education, gender, use of herbicides, use of fertilizer and access to extension services are negatively and significantly related to technical inefficiency. While age-squared is positively related to inefficiency. The negative signs of the parameters imply that the associated variables reduce inefficiency while the reverse is true for the positive signs. Thus, as age increases, farmers tend to be more productive however, there is evidence of life cycle effects with age-squared having a positive sign. This suggests that productivity increases with age but start to decline as farmer becomes very old

Student's t-test statistic was employed to verify the suitability of fertilizer and herbicides as "labour-saving" and "land-saving" technologies. The results show that use of fertilizer promotes production intensification, increases productivity per unit land and may therefore reduce quest for further land expansion. Fertilizer usage also increases net-income from cassava farming. Although farmers using herbicides have larger land holdings, their labour usage is significantly lower than those of the non-users. The estimates of Student's t-test statistic are shown in Table 5.

The Ultimate Way Forward

Although technical efficiency can be increased by as much as 10 percent, it is clear that most farmers in the study area are relatively efficient at the current state of technology and it is desirable that farmers should move to a higher level of technology. Technical change alters the structure of the production process by outward shift of isoquant, thereby changing resource productivity and the rate of return. This can be achieved by exploring means through which production possibilities can be enhanced such as substituting more productive and relatively abundant resources for inelastic and scarce resources (Olaide and Heady, 1982).

Given that improved cassava varieties have been widely adopted by cassava farmers, fertilizer should be made available to farmers at reasonable prices, as the varieties cultivated have been found to be highly responsive to fertilizer usage. Increased use of fertilizer will go a long way in promoting production intensification, thereby increasing per hectare yield, reducing cost of production and preventing further encroachment into forested areas by farmers in search for fertile lands. Finally, since use of herbicide has been found to exact a negative impact on technical inefficiency and it is also labour saving, substituting herbicides for labour is an innovative way of promoting competitive production. However, there is a need for intensified capacity building to ensure that farmers are provided with adequate knowledge and competent guide on the use on fertilizer and herbicides.

Table 3. Maximum likelihood estimates of Translog production function.

Variables	Parameters	Estimate (S.E)
Constant	β_0	1.042*** (0.063)
log of Labour	β_1	0.152** (0.071)
log of Stems	β_2	0.190 (0.217)
log of Herbicides	β_3	0.141** (0.056)
log of Fertilizer	β_4	0.084*** (0.030)
log of Land	β_5	0.434* (0.228)
0.5 X (log of Labour)^2	β_6	-0.030 (0.053)
0.5 X (log of Stems)^2	β_7	0.305 (0.301)
0.5 X (log of herbicides)^2	β_8	0.029* (0.016)
0.5 X (log of fertilizer)^2	β_9	0.009** (0.004)
0.5 X (log of Land)^2	β_{10}	0.339** (0.169)
log Labour X log Stem	β_{11}	-0.899*** (0.133)
log labour X log Herbicides	β_{12}	-0.003 (0.010)
log Labour X log Fertilizer	β_{13}	0.022 (0.114)
log Labour X log Farm size	β_{14}	0.779*** (0.110)
log Stem X log Herbicides	β_{15}	0.099*** (0.021)
log Stem X log Fertilizer	β_{16}	-0.063* (0.036)
log Stem X log Land	β_{17}	-0.503*** (0.176)
log Herbicides X log Fertilizer	β_{18}	0.002** (0.001)
log Herbicides X log Land	β_{19}	-0.115*** (0.019)
log Fertilizer X log Land	β_{20}	0.032 (0.037)
Sigma σ_v		0.111*** (0.011)
Sigma σ_u		0.107*** (0.018)
Sigma square		0.024*** (0.003)
Gamma γ		0.857*** (0.025)
Return to scale		1.001

*, ***, and *** = 10%, 5% and 1% level of significance respectively

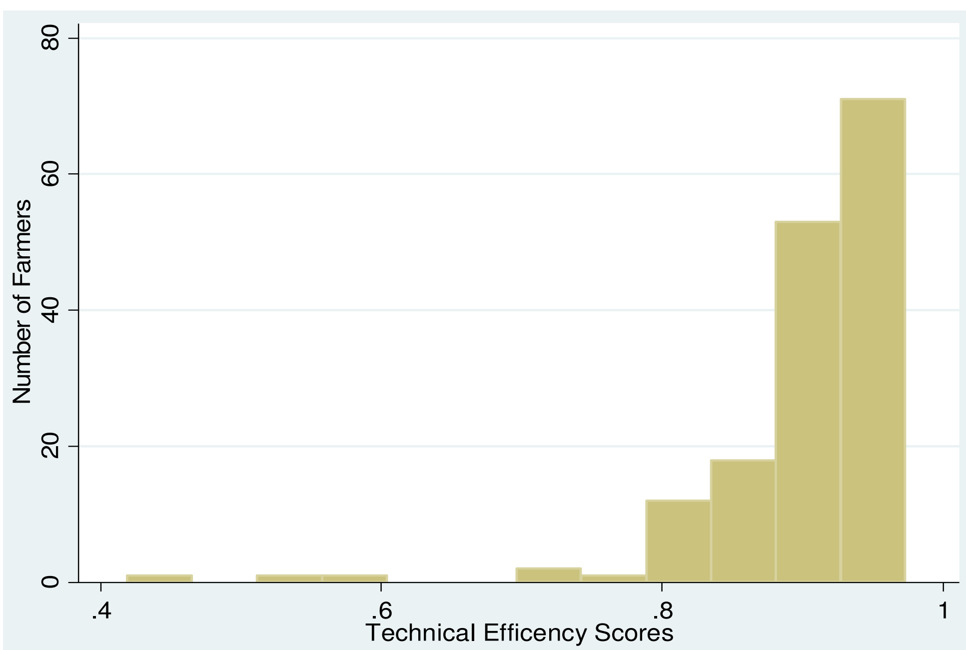

Figure 2. Distribution of Technical Efficiency of Cassava Farmers.

Table 4. Maximum likelihood estimates of the inefficiency model.

Variables	Parameter	Estimates (S.E)
Constant	δ_0	-5.48*** (1.151)
Age (years)	δ_1	-1.697** (0.814)
Age squared (years)	δ_2	0.014** (0.007)
Education (years)	δ_3	-0.051*** (0.017)
Gender (1=male, 0=female)	δ_4	-2.353*** (0.907)
Fertilizer usage (dummy)	δ_5	-2.57** (1.178)
Herbicides usage (dummy)	δ_6	-1.133** (0.056)
Membership of association (dummy)	δ_7	-0.219 (0.130)
Access to extension service (dummy)	δ_8	-1.663** (0.813)

*, ***, and *** = 10%, 5% and 1% level of significance respectively

Table 5. Student's t-test estimates of the effects of fertilizer and herbicides usage.

Fertilizer Effects	Users		Non-users		Difference	t-value
	Mean	SD	Mean	SD		
Farm size (Ha)	2.134	1.02	2.557	1.32	-0.423**	2.202
Labour (Mandays)	102.50	47.34	114.51	58.27	-12.01*	1.753
Yield (tons/ha)	19.46	3.98	18.06	3.72	1.399*	1.658
Net income ('000 Naira)	366.03	38.10	220.70	33.24	145.33**	2.381
Herbicide Effects	**Users**		**Non-Users**			**t-value**
Farm size (Ha)	2.722	1.22	1.886	1.123	0.837**	1.697
Labour (Mandays)	97.94	54.57	121.37	77.04	-23.43**	2.431
Yield (tons/ha)	18.06	3.72	17.18	3.98	0.880	1.222
Net income ('000 Naira)	265.32	38.46	242.51	30.80	22.82	0.847

*, ***, and *** = 10%, 5% and 1% level of significance respectively

Summary and Conclusion

Cassava is a very versatile crop used for both industrial and food purposes. It is a major staple food in most Nigerian homes and it is also useful in the industrial production of animal feed, ethanol, starch, adhesives, bio-fuels, drugs, plastics, packaging, stain remover, just to mention but a few. The present study investigates farm and non-farm constraints to competitive cassava production in Nigeria. Cross-section data were obtained from 160 farming households in Oyo and Ogun States in Southwestern Nigeria, using a multistage sampling procedure. Data collected were analyzed using descriptive statistics and stochastic frontier production function analysis. Summary statistics show that farmers are in their productive ages, they are quite educated and have access to improved cassava varieties. However, they have low access to chemical fertilizer and herbicides, and lack adequate knowledge of their usage**.** Technical efficiency scores range from 41.90 to 97.34 percent with an average score of 90.35. This shows that there is room for improvement and efficiency can still improve by 10 percent. Based on findings from this research, productivity can be enhanced by substituting more productive and relatively abundant resources for inelastic and scarce resources as well as improving the quality of extension services. These empirical insights provide useful guide to policy options to cassava commercialization, rapid industrialization and promoting overall competiveness

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