

## RESEARCH ARTICLE

## TECHNICAL EFFICIENCY DYNAMICS IN SMALLHOLDING CASSAVA-BASED FARMING IN RURAL NIGERIA

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## ABSTRACT

Dynamics of production efficiency is a key factor in assessing resource-use patterns and production growth. Raising technical efficiency of smallholder farmers in rural areas would not only increase their income but also stimulate the rest of the economy. This study therefore assessed movement of smallholder farmers in and out of technical efficiency regime over time in Nigeria. Panel data from Living Standard Measurement Survey was analysed using stochastic production frontier model, Markov chain and multinomial logit model. Farm size, labour, cassava cuttings and the use of pesticides, significantly influenced the productivity of cassava production while age squared, household size, no access to extension services and membership of a cooperative society reduced the efficiency of the farming households. A higher percentage (64.83%) of cassava farms under mono-cropping system were efficient in 2010/2011, while a large proportion of about 92.91% were inefficient in 2015/2016. Further, the rate of entry into technical inefficiency (31.32%) was more than the rate of exit from technical inefficiency (14.89%). Transition into technical inefficiency was explained by age, age squared, farm size, gender, household size, marital status, secondary school education and farming systems. In the long run, the probability that rural cassava farmers will be technically efficient was higher than that of being technically inefficient in the future.

## KEYWORDS

Marginal Productivity; Technical Inefficiency; Efficiency Transitions; Farming Systems

## 1. INTRODUCTION

Cassava is a drought-tolerant crop that is grown in all agro-ecological zones of Nigeria. It is also more tolerant to low soil fertility, pests and diseases than grains; and its roots has a long storage in the ground after maturity (Ope-Ewe et al., 2011; Ikuemonisan et al., 2020). Cassava farming is the livelihood of most smallholder rural households in Nigeria and with low cost of production and improved varieties, it has a high impact on the reduction of food insecurity and poverty among the smallholder farming households in Nigeria (Osun et al., 2014; Sanusi et al., 2022). Beyond being a famine reserve commodity, cassava also contributes to the country's Gross Domestic Product and has transformed from a staple to a cash crop in Nigeria. Although global cassava production has experienced consistent growth of well above 3% annually, its productivity is below the optimal level in African smallholder's farming systems (Kintché et al., 2017; FAO, 2018).

Nigeria is the highest producer of cassava in the world with production of about 54.8 million MT representing a world production share of 20.4% in 2017 but the country's average cassava productivity is low (FAO, 2019). Cassava farming is predominantly undertaken by over 6 million families, smallholder farming households using the traditional seed system of recycling stems from the previous harvest, which is mostly responsible for its poor yields in the country (SAHEL, 2016). The country has not been able to meet the demand of its growing population of about 167 million which equivalently connotes that it cannot meet up with the world's demand. This has brought about a drift to cassava production, which has served as a means of livelihood for millions of Nigerians and currently it's

a priority on the list of government and the international development agencies as a target crop for food security and agro-based industrialization. Thus, increasing the cassava output per unit of input use will ensure a least-cost combination of inputs and its competitiveness (Osun et al., 2014).

Although different government regimes had tried various means to encourage rural farmers to adopt modern cassava production technologies in order to increase productivity and efficiency, there are constraints to adoption in rural farming communities. Farmers in some instances reject some of the modern technology due to cultural backgrounds, illiteracy and religious beliefs. In the same vein, several programmes have been implemented to improve cassava production efficiency, some of which are IFAD-Assisted Cassava Multiplication Programme; the National Accelerated Industrial Crop Storage and Postharvest Technology Programme (NAICP), Agricultural Development Programmes (ADPs); the River Basin Development Authorities (RBDAs); the Directorate of Food, Roads and Rural Infrastructure (DIFRRI); the National Agricultural Land Development Authority (NALDA); the National Fadama Development Programme (NFDPP); the National Agricultural Technology Support Project (NATSP) (Odebo, 2012). Despite these programmes, the full yield potential of cassava has not been realized and the poverty situation has not improved enormously even in the face of continued intervention by government and donor funds as well as changing strategies (Eze and Nwobi, 2014). The ability of the agricultural policy makers to respond to this challenge is impaired by lack of basic information about agricultural sector (Obayelu and Ebute, 2016).

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Despite a key role that cassava plays in guaranteeing household food security in Nigeria, the potential of smallholder cassava farmers to address food insecurity are often constrained by of inadequate access to production resources, low adoption and use of improved technologies, climate variability, poor agronomic practices, inefficient use of production resources and low productivity (Okorie et al., 2021). The need to raise efficiency and output of small farmers in rural areas is therefore sine-qua-non to economic growth and attainment of zero hunger because it considers the extent to which output could be increased with limited scarce production resources (Bradshaw, 2006; Audu et al., 2013). With an ever-increasing Nigerian population, it is imperative to raise cassava productivity without jeopardising the factors of production meant for future time, in order to support the growing needs of the people (Sanusi et al., 2022). This suggests the need to analyse technical efficiency over time, which indicates the agricultural development of the country (Thakur et al., 2014). A dynamic analysis of efficiency in agricultural production is a crucial factor in tracking technological progress and productivity growth especially in developing agrarian economies, where resources are scarce and opportunities for developing and adopting better technologies are unstable (Pilo, 2019; Pan et al., 2022). Thus, a dynamic analysis of production efficiency is an important component in assessing capital accumulation patterns and growth over time (Stefanou, 2009). An understanding of changing pattern in technical efficiency in cassava production is a reliable agricultural planning index to assess cassava productivity development in the country.

Several studies in Nigeria had analysed the technical efficiency of agricultural products, other than cassava (Ajibefun, 2008; Orewa and Izekor, 2010; Alabi et al., 2010; Usman et al., 2012; Akhilomen et al., 2015). Other studies have analysed efficiency of cassava farmers (Oladejo and Oluwaranti, 2014; Audu et al., 2013; Eze and Nwibo, 2013; Okebiurun et al., 2018; Okorie et al., 2021) to explain why some farmers are more efficient than others. A few studies have analysed dynamics in technical efficiency in agricultural production of some other crops outside Africa (Thakur et al., 2014; Pilo, 2019; Ionescu, 2022; Nirere, 2022). Thus, there is a dearth of empirical studies on dynamics of technical efficiency in cassava production in Nigeria. The study therefore assessed how smallholder cassava farmers moved in and out of technical inefficiency over 2011 and 2016 farming seasons in rural Nigeria and what factors explained technical inefficiency dynamics in cassava production over the same period.

**2. MATERIALS AND METHODS**

Panel data from the Living Standard Measurement Survey (sourced from National Bureau of Statistics in conjunction with the Federal Ministry of Agriculture and Rural Development (FMA & RD), the National Food Reserve Agency (NFRA), the Bill and Melinda Gates Foundation (BMGF) and the World Bank (WB)) was used for the study. The panel data is a nationally representative survey of approximately 5000 households consisting of urban and rural enumeration areas. The data consists of three waves, 2010/2011, 2012/2013 and 2014/2015. However, this study was restricted to the information rural areas in Nigeria capturing farmers who are actively involved in cassava production in the first and third wave panel data. To a large extent, information was extrapolated from the two waves to identify movement of cassava-based farmers in and out of poverty, factors influencing these transitions and their production efficiency.

**2.1 Specification of Stochastic Production Frontier**

Stochastic production frontier model has its basis in the pioneer work of Farrell which has gone through various modifications and improvements (Farrell, 1957). Aigner and Chu translated Farrell's frontier into a production function and later, suggested the stochastic frontier approach (Aigner and Chu, 1968; Aigner et al., 1977; Meeuseen and van den Broeck, 1977; Battese and Corra, 1977). This approach simultaneously accounts for statistical noise and technical inefficiency which is useful in resolving the most serious deficiency in the deterministic frontier approach. This is expressed in such a way that only deviations that are influenced by controllable decisions are attributed to inefficiency. Following the work of using a panel data and a generalized production function, the model can be represented as equation (1) (Battese and Coelli, 1988; Kumbhakar et al., 2014):

$$Y_{it} = f(X_{it}; \beta) + \varepsilon_{it} \quad i=1, 2, \dots, n \text{ and } t=1, 2, \dots, T \tag{1}$$

Where *i* is the *n*th observations and *t* is the *T*th time periods. *Y<sub>it</sub>* is the output, *X<sub>it</sub>*, denotes the actual input vector, *β* is vector of production function and *ε* is the error term that is composed of two elements, that is

$$\varepsilon_{it} = V_{it} - U_{it} \tag{2}$$

Where *V<sub>it</sub>* is the symmetric disturbance, which is assumed to be identical, independent and normally distributed as *N* (0,  $\delta^2 vt$ ) given the stochastic structure of the frontier. The second component *U<sub>it</sub>* is a one-sided error term that is independent of *V<sub>it</sub>* and is normally distributed as *N* (0,  $\delta^2 ut$ ). It allows the actual production to fall below the frontier but without attributing all falls in output from the frontier as inefficiency.

In the same vein, the farms specific technical efficiency is defined in terms of observed output (*Y<sub>it</sub>*) to the corresponding frontier output (*Y<sub>it</sub><sup>\*</sup>*) using the available technology derived which is defined as:

$$TE_{it} = \frac{Y_{it}}{Y_{it}^*} = \frac{E(Y_{it} / U_{it}, X_{it})}{E(Y_{it} / U_{it=0}, X_{it})} = E(\exp(-U_{it}) / \varepsilon_{it}) \tag{3}$$

Technical efficiency (TE) takes values within the interval (0, 1) where 1 indicates a fully efficient firm.

The empirical stochastic frontier production model is specified using a Cobb-Douglas functional form, which is the basis for deriving efficiency measures and related cost frontier.

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + (V_i - U_i) \tag{4}$$

where the subscript *i* (*i*=1, ..., 6);

*Y* denotes output of cassava (kilogramme); *X<sub>i</sub>* is a vector of explanatory variables described in Appendix I (*i*= 1,2,3,...,n); *β<sub>i</sub>* are estimated coefficients; The random variables *V<sub>i</sub>* and *U<sub>i</sub>* are assumed to have the properties specified for the corresponding unobservable random variables in the frontier production function model; *U<sub>i</sub>* is modeled in terms of the factors that are assumed to affect the efficiency of production of the farmers. These factors are related to the socio- economic variables of the farmers. The determinants of technical inefficiency are specified as:

$$\mu_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + \delta_9 Z_9 + \delta_{10} Z_{10} \tag{5}$$

where:

*U<sub>i</sub>* = Technical inefficiency; *Z<sub>i</sub>* is a vector of socioeconomic exogeneous variables (Appendix I); and *δ<sub>1-10</sub>* are estimated parameters.

**2.2 Transition Matrix**

To investigate technical efficiency transitions (TET) in cassava farming in rural Nigeria, the techniques used by to measure the TET in rural Pakistan (Baulch et al., 1998). The items in the transition matrix will be shown in simple first-order Markov model and later converted into probability values of entering and exiting technical inefficiency by dividing each item by the corresponding row total to give the transition probability matrix below:

$$\begin{pmatrix} X_{11} & X_{12} \\ X_{21} & X_{22} \end{pmatrix}$$

In the same vein, vector of initial probability *P*(0) will be obtained by dividing each column total by the grand total. Thereafter, the proportion of households that will be in each category were expressed in the subsequent periods by using *P* (*k*) = *P* (0) *P<sup>k</sup>*

Where: *k* is the time period (wave). The long-term equilibrium (when the proportion of households entering technical inefficiency equals the proportion exiting it) will be obtained by using:

$$eP = e (e_1, e_2) \begin{pmatrix} X_{11} & X_{12} \\ X_{21} & X_{22} \end{pmatrix} = (e_1, e_2)$$

The solution to the above matrix produced *e<sub>1</sub>*, *e<sub>2</sub>*, which are the proportion of households that will always be efficient, and always inefficient at equilibrium in the long run.

Where:

*e<sub>1</sub>* = probability of households that will be efficient at equilibrium

*e<sub>2</sub>* = probability of households that will be always inefficient at equilibrium

The multinomial logit model was used to examine the determinants of technical efficiency transitions between the two waves. The model is designed to predict the probabilities of the different possible outcomes of a categorically distributed dependent variable when given a set of independent variables. The model is employed when the dependent variable is a limited set of items that cannot be meaningfully ordered, as well as independent variables which are used to predict the dependent variable. The multinomial logit regression model is given as:

$$Pr(Y_i = j) = \frac{e^{(X_{ij}\lambda + \tau V\hat{E}P_{ij,t-1})}}{\sum_{k=0}^3 e^{(X_{ij}\lambda + \tau V\hat{E}P_{ij,t-1})}}, j = 0,1,2,3 \tag{6}$$

second period (exiting inefficiency)

$Y_0$  = technically inefficient in both periods (i.e. chronically or always technically inefficient)

$X_n$  = a vector of the explanatory variables where  $n = 1, 2, 3, \dots, n$  (Appendix).

### 3. RESULTS

#### 3.1 Summary Statistics of Continuous Socioeconomic Characteristics of Cassava Farmers

The mean age of household heads was 54 years across the two waves but the average farm size increased from 1 to 7 hectares between 2010 and 2015 (Table 1) The mean dependency ratio, measured as the number of dependents in the household divided by the number of working class people, increased from 1 to 13 between the panel waves Furthermore, the household size which is defined as the number of persons within the household is seen to have a mean which increased from one to seven persons per household while the per capita expenditure which is defined as the ratio of total household expenditure by the household size of cassava farmers increased from ₦40000 to ₦75000 from 2010 to 2015. Concisely, cassava farmers in rural households also increased the amount spent on pesticides from ₦48000 to ₦60000 between the two waves which implies that they adopted the use of pesticides over the years in order to prevent crop loss.

The model can be explicitly expressed below :

$$Y_1 = \alpha_0 + \beta_{11}X_1 + \beta_{21}X_2 + \dots + \beta_n X_n + \epsilon_i \tag{7}$$

$$Y_2 = \alpha_2 + \beta_{12}X_1 + \beta_{22}X_2 + \dots + \beta_n X_n + \epsilon_i \tag{8}$$

$$Y_3 = \alpha_3 + \beta_{13}X_1 + \beta_{23}X_2 + \dots + \beta_n X_n + \epsilon_i \tag{9}$$

$$Y_0 = \alpha_0 + \beta_{10}X_1 + \beta_{20}X_2 + \dots + \beta_n X_n + \epsilon_i \tag{10}$$

Where  $Y_i$  represents 4 unordered categories of technical efficiency transition:

$Y_1$  = Never technically in-efficient)

$Y_2$  = Technically efficient production in the first period, but non-technically efficient in the second period (i.e. entering technical inefficiency)

$Y_3$  = Technical in-efficient in the first period, but technically efficient in the

Table 1: Summary Statistics of Socio-economic Characteristics of Cassava Farmers				
Variable	2010/2011		2015/2016	
	Mean (Standard deviation)	Minimum (maximum)	Mean (Standard deviation)	Minimum (maximum)
Farm size (Hectares)	0.153395 (0.04070)	0.0020 (1.1272)	0.6022219 (1.027288)	0 (7.7794)
Age (years)	54.2647 (5.8440)	15 (999)	54.16052 (13.03897)	17 (103)
Household size	5.8440 (2.9214)	1 (23)	7.302936 (3.026764)	1 (21)
Pesticides	5360.46 (8262.136)	120 (48000)	1541.616 (7135.4430)	0 (60000)
Per capita expenditure	514.035 (16380.42)	0 (40,0000)	11920.32 (9088.358)	375 (75000)
Dependency ratio	0.4318 (0.24352)	0 (1)	1.806821 (2.37851)	0 (13)

#### 3.2 Marginal Productivity and Technical Inefficiency of Cassava Farming

Table 2: Marginal Productivity and Technical Inefficiency				
Variable	Wave 1		Wave 3	
	Coefficients	Standard Error	Coefficients	Standard Error
Marginal Productivity				
Constant	4.0118	2.1267	8.3153	0.8237
Ln ( Farm size)	0.2605	1.1500	0.5261***	0.0881
Ln (labour)	0.1447	0.0963	0.0155***	0.0025
Ln ( cassava cuttings )	0.0069***	0.0021	0.1264***	0.0226
Ln ( Fertilizer)	0.3424**	0.1830	0.0175	0.0686
Ln ( pesticides)	0.2701*	0.1671	0.3881***	0.0741
<b>Inefficiency Model</b>				
Constant	1.6511	0.9054	10.7593	0.5468
Age	-0.0707**	0.0284	0.0179	0.0188
Age squared	0.0006**	0.0002	-0.0002	0.0002
Gender	-0.0581	0.2471		
Household size	0.0788**	0.0457	0.0799***	0.0128
Marital status	0.0878	0.2701		
Access to credit	0.0406	0.2348	0.0361	0.0923
Access to extension			0.6170***	0.1750
Membership of an association	0.2467**	0.1365	-0.6869***	0.1201
Inter- cropping	0.1324	0.3480	0.2992*	0.1871
Mixed Cropping	0.2140	0.1378	0.0421	0.0833
Alley cropping	-0.8231***	0.2489	-1.8641**	1.0004
Relay Cropping			1.7501	0.3855
Variance parameter				
Sigma squared	2.8756	6117304	3.2275	0.3093
Lambda	1.2401	0.4481	3.1046	0.1525
Log likelihood	-462.28424		-725.9752	

\*\*\* Significant at 1%, \*\* Significant at 5%, \* Significant at 10%

The parameters and related statistical test results obtained from the stochastic frontier production function analysis is presented in Table 2. The result revealed that the estimated coefficient for farm size, labour and cassava cuttings were positive in both waves implying that a unit increase in farm size, labour and cassava cuttings will result in a significant

increase in the cassava output in the study area. In the same vein, coefficient of cassava cutting was positive and significant at 1-percent in both waves, implying that a unit increase in the cassava cutting will result in 0.0069 and 0.1264 increase in cassava output. Finally, the coefficient of fertilizer was significant in wave 1, while that of pesticides was significant

in both waves. The findings are also agreed with that of Ogundari and Ojo that coefficients for the price of labor, price of planting materials, price of Agrochemicals and the price of farm tools also had positive marginal physical productivity (Ogundari and Ojo, 2006).

**Table 3: Average Technical Efficiency of Cassava Farmers in Rural Nigeria.**

Total Farm Level	Mean Efficiency Estimate (Standard Deviation)	Minimum Efficiency Estimates	Maximum Efficiency Estimates
Technical Efficiency 2010	0.6203 (0.2867)	0.02867	1
Technical Efficiency 2015	0.7783 (0.4727)	0.6854	1

Furthermore, socioeconomic factors included in the inefficiency model were age, age squared, gender, Marital status, household size, extension visit, access to credit, membership of the farmers' association and farming systems (Table 2). The coefficient of Age squared was positive and significant in wave one. Extension visits had a positive coefficient of 0.6170 in wave 3. Also the coefficient of Age squared was positive and significant in wave one. Extension visit also had a positive coefficient of 0.6170 in wave 3. Membership of the farmers' association was positively related to the farmer's technical efficiency in waves 1 and 3. The result showed vividly that cassava intercropped with crops increased technical inefficiency in wave 3, while alley cropping (planting of row trees with cassava) had a reduction in technical inefficiency in both waves. The mean level of technical efficiency increased from 0.6203 in 2010 to 0.7783 in wave 3 (Table 3).

**3.2 Technical Efficiency Transition Matrix of Cassava-Based Farmers**

The rate at which cassava farmers enter the state of been technically inefficient (31.32%) was more than the rate of exit from technical

**3.3 Determinants of Technical Efficiency Transitions.**

**Table 5: Determinants of Technical Efficiency Transitions Among Cassava-Based Rural Farmers**

Variable	Always Technically efficient		Entering technical inefficiency		Exiting technical inefficiency		Always technically inefficient
	Coefficient	Marginal effect dy/dx	Coefficient	Marginal Effect dy/dx	Coefficient	Marginal Effect dy/dx	Marginal Effect dy/dx
Age	0.1340 (0.0919)	0.0046 (0.0041)	0.0868** (0.0352)	0.0147** (0.0069)	0.0257 (0.0658)	-0.0008 (0.0042)	-0.0186** (0.0073)
Age squared	-0.0013 (0.0008)	-0.0000 (.0000)	-0.0010*** (0.0003)	-0.0002*** (0.0001)	-0.0004 (0.0006)	0.0000 (0.0000)	0.0002*** (0.0001)
Farm size	0.2683** (0.1159)	0.0217*** (0.0054)	-0.7772*** (0.1315)	-0.16231*** (0.0248)	0.2319** (0.1004)	0.0291*** (0.0067)	0.1116*** (0.0222)
Gender	0.3256 (0.8175)	0.0142 (0.0431)	-0.4247 (0.2641)	-0.1022** (0.0449)	0.8780 (0.6865)	0.0802 (0.0705)	0.0078 (0.0687)
Household size	0.0075 (0.0460)	0.0001 (0.0019)	-0.0691*** (0.0227)	-0.0180*** (0.0042)	0.2133*** (0.0326)	0.0153*** (0.0021)	0.0026 (0.0044)
Credit access	-1.008*** (0.2651)	-0.0423*** (0.0153)	-0.2103 (0.1545)	-0.0023 (0.0292)	-0.9713*** (0.2229)	-0.0609*** (0.0180)	0.1055*** (0.0310)
Access to extension	0.4081 (0.4725)	0.0065 (0.0225)	0.3906 (0.2770)	0.0492 (0.0545)	0.8804** (0.3591)	0.0578** (0.0332)	-0.1135** (0.0552)
Marital Status	-0.6661 (0.7752)	-0.0267 (0.0246)	0.3844 (0.2391)	0.1016** (0.0492)	-0.8071 (0.6598)	-0.0489 (0.0311)	-0.0261 (0.0536)
Primary Education	-0.1007 (0.6033)	0.0017 (0.0255)	-0.1077 (0.3091)	-0.0031 (0.0595)	-0.6049 (0.4929)	-0.0476 (0.0457)	0.0490 (0.0670)
Secondary Education	-0.5437 (0.6418)	-0.0080 (0.0264)	-0.5800** (0.3239)	-0.0811 (0.0616)	-1.1047** (0.5200)	-0.0682 (0.0461)	0.1573** (0.0694)
Tertiary Education	-0.0113 (0.6547)	0.0156 (0.0298)	-0.5197 (0.3439)	-0.0773 (0.0649)	-1.0571** (0.5505)	-0.0692 (0.0470)	0.1308** (0.0731)
Membership of association	-0.0737 (0.3638)	-0.0019 (0.0163)	0.2113 (0.2255)	0.0560 (0.0396)	-0.6420** (0.2935)	-0.0544 (0.0258)	0.0003 (0.0429)
intercropping	0.5125*** (0.1165)	0.0191*** (0.0054)	0.1392*** (0.0437)	0.0138* (0.0083)	0.3295*** (0.0845)	0.0159*** (0.0054)	-0.0488*** (0.0089)
Number of observations	1,458						
Log likelihood	-						
LR chi <sup>2</sup> (16)	1371.7503						
Prob> chi <sup>2</sup>	283.30						
Pseudo R <sup>2</sup>	0.0000						
	0.0936						

Note: \*\*\*, \*\* & \* represent significant levels at 1%, 5% and 10%, respectively

inefficiency (14.89%) (Table 4). About 56% of cassava farmers in rural Nigeria were always technical inefficient. Furthermore, about 14 percent of cassava farmers who were technically efficient in 2010 remained efficient in 2015, while 86 percent of those who were technically efficient in 2010 entered the level of been technically inefficient in 2015. In the same manner, 12 percent of those who were technically inefficient in 2010 moved into a state of been efficient in 2015; while 88 percent of those that were technically inefficient in 2010 remained in the same state in 2015. Furthermore, analysis of the probability transition matrix reveals that at the short run, the probability that a cassava farmer will be technically efficient is 12.7 percent while the probability that they will be technically inefficient in the short run-in rural Nigeria is 87.3 percent. On the long run, the probability that rural cassava farmers will be technically efficient (76 percent) than the probability that they will remain technically inefficient in the future (12 percent).

**Table 4: Technical Efficiency Transition Matrix of Cassava-Based Farmers**

		Wave 3		
		Wave 1	Efficient	Inefficient < 0.7783
Wave 1	Efficient	73 (0.1352)	467 (0.8648)	540
	Inefficient < 0.6203	116 (0.1220)	835 (0.8789)	951
	Total	189	1302	
Vector of initial probability		0.1268	0.8732	
Steady state probability		0.076	0.012	

\*\*Figures in parenthesis represent the probability transition matrix

The result of the multinomial regression revealed that the model passed the minimum requirement for robustness where the log likelihood is -1371.7503 was significant ( $p < 0.001$ ) implying that the model has a good fit. Farm size, household size, access to credit and mixed cropping farming system were significant factors influencing the likelihood of a cassava-based farm being always technically efficient. Furthermore, the factors which determine the movement of farmers into technical inefficiency in cassava production were age, age squared, farm size, gender, household size, marital status, secondary school education and mixed cropping systems. On another hand, farm size, household size, credit access, access to extension, secondary education, tertiary education, membership of association and farming systems were significant determinants of cassava farmers who were exiting technical inefficiency while age, age squared, farm size, credit access, access to extension, secondary education, tertiary education, membership of association and farming systems play a significant role among farmers who were always technically inefficient.

#### 4. DISCUSSION

Farmers in the area were relatively aging and this may limit their technical efficiency. Farming activities were also in the hands of with increase in household size, dependency ratio and per capita expenditure. Increased the amount spent on pesticides could have positive implication for improved technical efficiency through reduction of output loss. A unit increase in farm size would result in a significant increase in the cassava output in the study area. This agrees with the finding of Nahanga and Becvarova that the positive coefficients for land were expected and that the use of more land will lead to a greater output (Nahanga and Becvarova, 2015). Cassava production is also labour intensive from production till harvesting. A unit increase in the cassava cutting would also increase cassava output. This is in contrast to the findings of a group researchers that coefficient of cassava cuttings was negative; implying that there is an inverse relationship between cassava cutting and cassava output in the area (Okebiurun et al., 2018). The findings are also agreed with that of Ogundari and Ojo that coefficients for the price of labor, price of planting materials, price of agrochemicals and the price of farm tools had positive marginal physical productivity (Ogundari and Ojo, 2006).

Extension contact reduced technical inefficiency through increased farmers' awareness about innovation. This result is in line with the findings of that extension services enable farmers to combine inputs more efficiently (Waziri et al., 2015). Membership of the farmers' association increases farmers' interaction with fellow farmers, non-farmers and extension agents. This improvise farmers' methods of production and prevent irrational utilization of resources. In the same vein farming system also contributed to the factors that affect the technical efficiency of cassava based farmers. Contrary to expectation, cassava intercropped with arable crops increases inefficiency in cassava production. On the other hand, planting of row trees with cassava reduced technical inefficiency in cassava production in both waves. This is because an optimized choice for crop species and management in different stages of the alley cropping systems enhances land use efficiency and subsequently technical and economic efficiencies in farming (Xu et al., 2019).

There was an increase in the level of input use for maximum output among the farming households. The increase in technical efficiency in wave 3 may be as a result of the Growth Enhancement Scheme (GES) under the Agricultural Transformation Agenda (ATA) during 2011-2016 period. This has however brought about a reduction in the cost of production as well as contributes to increase in revenue generated from sales of cassava product (FMARD, 2016). The implication of this is that there will be reduction in poverty among cassava farming households as well as improve their overall welfare. More than half of the cassava farmers in rural Nigeria were always technical inefficient implying that high technical inefficiency increases the likelihood of low output and consequently, low standard of living (Audu et al., 2013). Thus, raising efficiency and output of small farmers in rural areas would not only increase their income but also stimulate the rest of the economy and contribute to food security and poverty reduction on a large scale. Furthermore, analysis of the probability transition matrix reveals that at the short run, the probability that a cassava farmer will be technically inefficient in the short run was higher than being technically efficient in rural Nigeria. However, the probability that rural cassava farmers will be technically efficient in the long-run was higher than the probability that they will remain technically inefficient. This suggests a promising future for cassava production in Nigeria.

Age had a positive relationship with the likelihood of entering technical inefficiency, indicating TE decreases with increase in age. The reason for

this relationship may be due to the fact that old age farmers may be unwilling to take risk and they prefer to stick to their traditional way of production. Another cogent reason may be to evade frequent experimentation with the new advent of technologies. Farm size is probably one of the most important factors in crop small-holder production system in rural Nigeria. Large farm size can enable a farmer to increase as well as diversify the scale of production. Farm size had a positive relationship with the probability that farmers would always be technically efficient in rural Nigeria, while the relationship was negative among farmers who were entering technical inefficiency. This outcome is consistent with the findings of Asogwa and Umeh that households with large farm sizes tends to be efficient in resource use and adopts mechanization more than small farm size holders (Asogwa and Umeh, 2012).

Farm mechanization is expected to increase farm size and improve farm level efficiency and production (Vortia et al., 2021). While the negative effect of farm size on the categories of farmers who were entering technical inefficiency could be linked to the fact that the land was underutilized as a result of not been capable to employ modern technologies in production. Furthermore, the gender of cassava household heads had a negative effect on the status of farmers who were entering technical inefficiency. This is an indication that female farmers in rural Nigeria are often hindered by gender related curtailment and unequal access to productive resources which in turn has reduced their productive capacity when compared with other male farmers. The result of the analysis shows a significant and negative relationship between household size and farmers who were entering technical inefficiency in rural Nigeria. As expected, households with larger family are more vulnerable to technical inefficiency than those with smaller size.

Farmers who have greater access to credit increases the probability of exiting technical inefficiency in cassava production. This is because access to credit however helps to finance the procurement of material inputs which have a positive effect on cassava production. This agrees with the findings of that access to credit positively impacts the technical efficiency of smallholder cassava farmers in Ghana (Missiame et al., 2021). Adoption of innovations on cassava production would also increase the level of technical efficiency in cassava-based farming. In the same vein, Formal education would increase production efficiency but negatively impacts the likelihood of entering into technical inefficiency. The relevance of this is that education is an important factor for enhancing agricultural productivity and the implication is that farmers with more years of formal schooling tend to be more efficient in cassava production, presumably due to their enhanced ability to acquire technical knowledge which makes them closer to the frontier output. Educated farmers have better access to new technologies of farming and prices of inputs. Hence, they also have eagerness to adopt modern inputs and technologies more optimally and efficiently, which aligns with the findings (Ike and Inoni, 2006).

Technically inefficient farmers did not belong to any cooperative society due to the fact that most cassava farmers in rural Nigeria had limited access to pooled productive resources in cooperative societies (Odurukwe et al., 2003). In conclusion, farming system also contributed to the factors that affect technical efficiency transition levels of cassava-based farmers. The result showed vividly that intercropping of cassava with other crops was positively related to the probability of being technically efficient and exiting technical inefficient. This is because mixed farming system recycles much of its wastes, re-utilizes farm limited resources and increases the area cultivated where animal draught is used. (Putra et al., 2019).

#### 5. CONCLUSION

The study showed that there was increased level of input use for maximum output in cassava production, which would reduce the cost of production and increase in revenue generated from sales of cassava product. Drivers of technical inefficiency in cassava production were age squared, household size, membership of association and no access to extension services. In the long run, the probability that rural cassava farmers will be technically efficient was higher than that of being technically inefficient in the future is 12 percent. Farms with larger sizes were more likely to be efficient and move out of inefficiency, while those with smaller sizes were more likely to be inefficient and move into technical inefficiency. Thus, it is expedient for policy makers to intensify on farm mechanization projects for smallholder farmers that will help them to increase their level of technical efficiency via the reduction of underutilization of their farmlands. Cassava development programs in Nigeria should specifically target female cassava farmers, so that they can have improve access production assets and information, which will in turn increase their efficiency as well as the farmers' overall welfare.

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