2015-06-01

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http://hdl.handle.net/10026.1/4494

Journal of Agriculture and Rural Development in the Tropics and Subtropics

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February 2015

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Abstract

The present study examines the level of pure technical and scale efficiencies of cassava production system including its sub-processes (that is production and processing stages) of 278 cassava farmers/processors from three regions of Delta State, Nigeria by applying Two-Stage Data Envelopment Analysis (DEA) approach. Results reveal that pure technical efficiency (PTE) is significantly lower at the production stage 0.41 vs 0.55 for the processing stage, but scale efficiency (SE) is high at both stages (0.84 and 0.87), implying that productivity can be improved substantially by reallocation of resources and adjusting operation size. The socio-economic determinants exert differential impacts on PTE and SE at each stage. Overall, education, experience and main occupation as farmer significantly improve SE while subsistence pressure reduces it. Extension contact significantly improves SE at the processing stage but reduces PTE and SE overall. Inverse size-PTE and size-SE relationships exist in cassava production system. In other words, large/medium farms are technically and scale inefficient. Gender gap exists in performance. Male farmers are technically efficient at processing stage but scale inefficient overall. Farmers in northern region are technically efficient. Investments in education, extension services and infrastructure are suggested as policy options to improve the cassava sector in Nigeria.

Key words: Pure technical efficiency, scale efficiency, Two-Stage DEA approach, cassava production and processing stages, Delta state, Nigeria.

1. Introduction

Cassava is an important crop that has great potential to support agricultural growth in Nigeria because of its wide range of use spanning consumption to its use in industries. Nigeria is a leading producer of cassava in Africa (Ayoade & Adeola, 2009; Knipscheer *et al.*, 2007; Nweke, 2004). Cassava is identified as a promising crop for international trade, as

demand for cassava derivatives, e.g. gari (a type of processed cassava), starch and tapioca doubled over the last two decades (Nweke, 2004).

However, the average yield level of cassava in Nigeria is low, estimated at 14.7 mt ha^{-1} (Nang'ayo *et al.*, 2007) compared with 19 mt ha^{-1} in Indonesia, which is also a tropical country where production is similarly constrained by low level of input use, high variability in commodity prices, and inadequate infrastructure (Sugino & Mayrowani, 2009). Currently, more than 80% of cassava root tuber (CRT) is primarily produced for food (e.g. gari, akpu, tapioca and starch) and only 16% for industrial uses and export (Ayoade & Adeola, 2009; Knipscheer *et al.*, 2007; Nweke, 2004). Gari are fine white/yellow granules which are processed from harvested CRT and then peeled, grated into pulp, fermented, dried and roasted into fine granules. Akpu is a pasty product of cassava, which is first fermented and then sieved to remove unfermented midrib and fibres and then boiled or cooked and pounded to a pasty moulded product. Tapioca is produced from peeled CRT which is first sliced into chips, then soaked, fermented, dried or roasted into dried flakes. Further processing involves grinding and milling into flour (Rahman & Awerije, 2014).

Cassava processing at the household level is an important income generator in poor rural areas, particularly for women, and has good potential to contribute to economic diversity and could create opportunities for consumption and processing industries (Kaine, 2011; Odebode, 2008; Echebiri & Edaba, 2008; Nweke, 2004).

Many studies (e.g. Falayan & Bifarin, 2011; Wihemina *et al*, 2009; Kaine, 2011) noted that adding value through processing of CRT improves return on investment. Also, the problem of spoilage of CRT could be overcome through processing (Chukwuji *et al.*, 2007; Farinde *et al.*, 2007). Processing also increases shelf-life in storage and addition of value increases marketing margin of the processors (Kaine, 2011; Chukwuji *et al.*, 2007).

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However, realisation of the full potential of cassava as a profitable crop is perhaps greatly affected by its low level of productivity and efficiency.

A number of studies examined production efficiency of CRT only in Nigeria and elsewhere in Africa (Oladeebo & Oluwaranti, 2012; Kaine, 2011; Ogundari & Brummer, 2010; Iheke, 2008; Erhabor & Emokaro, 2011; Udoh & Etim, 2007; Chukwuji *et al.*, 2007; Ogundari & Ojo, 2006; Okorji *et al.*, 2003). Naziri *et al.* (2014) provided a detailed estimation of physical losses in cassava in various stages of processing in Ghana, Nigeria, Thailand and Vietnam. The physical loss of cassava in Southwestern Nigeria is estimated at 481,258 ton per year accounting for 6.7% of total production and 82% of the physical loss takes place during processing stage alone. Therefore, given such a large extent in losses, it is very important to examine efficiency of cassava both at the production stage as well as processing stage. However, to our knowledge no single study has evaluated overall efficiency of cassava as a production system which is composed of two sub-processes or stages: (i) production stage where raw CRT is produced; and (ii) processing stage where the output of the first stage (i.e., CRT) serves as an input along with other material inputs to produce gari (the processed form of cassava mainly used for consumption). The key contribution of our research to the existing literature is that we are evaluating performance of cassava farmers/processors by examining efficiencies at each stage (i.e., production and processing) and the overall system, which can shed light on low level of cassava processing despite its income generating potential. We do this by applying Two-Stage Data Envelopment Analysis (DEA) approach and also identify socio-economic determinants of observed efficiencies at each stage using a fractional logit model, so that well-informed decisions can be made.

2. METHODOLOGY

2.1 Analytical framework: the Two-Stage DEA approach

Data Envelopment Analysis (DEA), a non-parametric approach, has been widely applied to measure relative efficiency of decision making units (DMUs) applying same type of inputs to

produce same type of outputs (Charnes *et al.*, 1978). An advantage of DEA is its capacity to analyse production technologies characterised by multiple outputs and multiple inputs without assuming any functional form or behaviour of the DMUs or markets. The analysis provides DMU specific relative efficiency measures in comparison to its most efficient peers so that one can identify what factors are responsible for inefficient performance of DMUs.

Therefore, efforts have been made to break down the overall efficiency into components so that the specific sources of inefficiencies can be identified. For example, Banker *et al.* (1984) break the overall efficiency of a DMU into the product of scale efficiency and technical efficiency, which is decomposition on the structure of production. Scale efficiency refers to the level of efficiency that can be achieved by operating at an optimal scale or firm size. Technical efficiency is defined as the ability to produce a given level of output by using minimum set of inputs (an input oriented measure) or produce the maximum level of output by using a given set of inputs (an output oriented measure (Coelli *et al.*, 2005).

Another type of decomposition focuses on the stages of the production process. Here, the production process is divided into sub-processes where output from one sub-process enters as input into another sub-process. Seiford & Zhu (1999) and Zhu (2000) applied this framework to examine profitability and marketability of US banks and Fortune 500 companies, respectively. Both Seiford & Zhu (1999) and Zhu (2000) assumed that each of these sub-processes is independent of each other, and therefore, analysed relative efficiencies of each stage and the overall process independently.

We adopt this Two-Stage DEA framework in analysing relative efficiencies of cassava production system where CRT produced from the first stage is used as input along with other inputs in the second stage to produce the final output, gari. We further decompose the overall measure of production/technical efficiency (TE) of each stage into measures of 'pure technical efficiency (PTE)' and 'scale efficiency (SE)'. In other words, we combined decomposition of the cassava production system into stages of production process (Seiford

& Zhu, 1999) as well as structure of production in each stage (Banker *et al.*, 1984), which is not commonly seen in agricultural productivity and efficiency literature.

2.2   The Two-Stage DEA model

The models for solving cassava production system are as follows. Denote $X_{ij}, i = 1, ...m$ as the ith input and $Y_{rj}, r = 1, ...s$ as the rth output of DMU j, $j = 1, ...n$. Then the conventional DEA model to measure efficiency of DMU k under the assumption of constant returns to scale (CRS) is given by:

$$E_k = Max \sum_{r=1}^{s} u_r Y_{rk}$$

$s.t.$

$$\sum_{i=1}^{m} v_i X_{ik} = 1$$

$$\sum_{r=1}^{s} u_r Y_{rk} - \sum_{i=1}^{m} v_i X_{ik} \leq 0, j = 1, ...n$$

$$v_i, u_r \geq \varepsilon, i = 1, ...m, r = 1, ...s \qquad (1)$$

where E_k is the relative efficiency of DMU k. A value of $E_k = 1$ indicates fully efficient and $E_k < 1$ indicates existence of inefficiency for DMU k.

Figure 1 presents the production system of cassava which is composed of two sub-processes, production of the CRT (Stage 1), and then processing into gari (Stage 2). The whole process uses m inputs, $X_{ik}, i = 1, ...m$ to produce s outputs, $Y_{rk}, r = 1, ...s$. Unlike the conventional single stage production process, in our Two-StageTwo-Stage framework, the production system provides q intermediate products, $Z_{pk}, p = 1, ...q$, which are the outputs of stage 1 but are used as inputs in stage 2 along with other inputs $X_{ik}, i = 1, ...m$. Therefore, the Two-Stage DEA model adopted here following Seiford & Zhu (1999) and Zhu (2000), is to use Eq (1) to measure the overall efficiency of the production system and the following equations (2a) and (2b) to measure efficiencies of stage 1, E_k^1, and stage 2, E_k^2, respectively:

$$E_k^1 = Max \sum_{p=1}^{q} w_p Z_{pk}$$

$s.t.$

$$\sum_{i=1}^{m} v_i X_{ik} = 1$$

$$\sum_{p=1}^{q} w_p Z_{pk} - \sum_{i=1}^{m} v_i X_{ik} \leq 0, j = 1, \dots. n$$

$$v_i, w_p \geq \varepsilon, i = 1, \dots. m, p = 1, \dots. q \qquad\qquad (2a)$$

$$E_k^2 = Max \sum_{r=1}^{s} u_r Y_{rk}$$

$s.t.$

$$\sum_{p=1}^{q} w_p Z_{pk} = 1$$

$$\sum_{r=1}^{s} u_r Y_{rk} - \sum_{p=1}^{q} w_p Z_{pk} - \sum_{i=1}^{m} v_i X_{ik} \leq 0, j = 1, \dots. n$$

$$u_r, v_i, w_p \geq \varepsilon, i = 1, \dots. m, p = 1, \dots. q, r = 1, \dots. s \qquad\qquad (2b)$$

The efficiencies of the whole process and the two sub-processes are calculated independently.

Inputs:
Land (X_1)
Labour (X_2)
Fertiliser (X_3)
Seed (X_4)

Production stage

Cassava root tuber (Z_1)
Processing labour (X_5)
Materials (X_6)

Processing stage
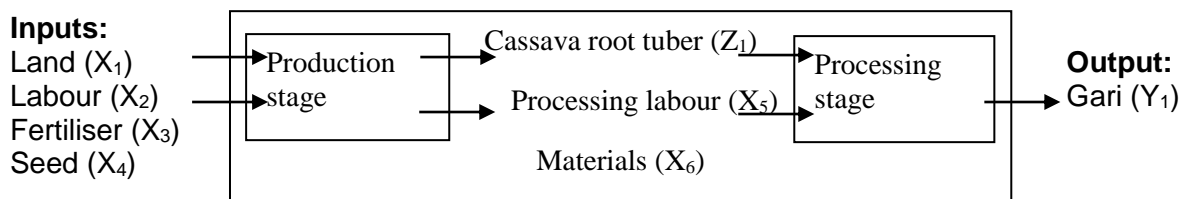
Output:
Gari (Y_1)

Figure 1. The cassava production system

Since all these models assume CRS technology, DMUs which are operating under increasing returns to scale (IRS) or decreasing returns to scale (DRS) will be termed inefficient (Zhu 2000). It is useful to know not only the level of technical efficiency but also the level of scale efficiency of these cassava farmers/processors. Therefore, we evaluate the

DMUs in the context of variable returns to scale (VRS) by imposing an additional constraint in each model, $\sum_{j=1}^{n} \lambda_i = 1$. For example, Eq (1) now becomes:

$$E_k = Max \sum_{r=1}^{s} u_r Y_{rk}$$

$s.t.$

$$\sum_{i=1}^{m} v_i X_{ik} = 1$$

$$\sum_{r=1}^{s} u_r Y_{rk} - \sum_{i=1}^{m} v_i X_{ik} \leq 0, j = 1, \dots . n$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0, j = 1, \dots . n$$

$$v_i, u_r \geq \varepsilon, i = 1, \dots . m, r = 1, \dots . s \qquad (1a)$$

The VRS efficiency score is termed as the pure technical efficiency (Coelli, 1996). Scale efficiency is defined by the ratio of CRS technical efficiency score (TE) to VRS technical efficiency score (PTE). If this ratio is equal to one, then a DMU is scale efficient; if the ratio is less than one, then a DMU is scale inefficient. In this formulation, TE = PTE*SE.

2.3   Determinants of efficiency: a fractional logit model

Since the DEA efficiency scores are bounded and typically lie between $0 < \theta \leq 1$, we apply the recently introduced fractional regression model by Papke & Wooldridge (2008) which keeps the predicted values of the conditional mean of the fractional response in the unit interval. Ramalho *et al.* (2011) noted that if large proportion of the fractional data (i.e. efficiency scores) strictly lie above the 0 threshold but do not reach the upper boundary of 1, then a one-part analysis of the data is sufficient. Therefore, a single step fractional logit model, as adopted also by Awerije & Rahman (2014) and Gelan & Muriithi (2012), is applied in this study.

In simple terms, the one-part analysis involves only those observations with $y = \in (0, 1)$ for which a conditional mean or a parametric model is employed by assuming a particular distribution of the fractional variable (Ramalho *et al.*, 2011). The conditional mean of the dependent variable (i.e. efficiency scores θ) is given by (Ramalho *et al.*, 2011):

$$E(y|x) = G(x\theta) \qquad (3)$$

where G(.) is the known linear function satisfying $0 \leq G(.) \leq 1$. The study assumes $G(.)$ to be a logistic distribution function defined as:

$$G(x\theta) = \frac{e^{x\theta}}{1+e^{x\theta}} \qquad (4)$$

The derivative with respect to the index $x\theta$ is given by:

$$g(x\theta) = \partial G(x\theta)/\partial x\theta \quad (5)$$

and the link function $h(\mu)$ is given by (Ramalho *et al.*, 2011):

$$h(\mu) = ln\frac{\mu}{1-\mu} \qquad (6)$$

The link function $h(\mu)$ is a widely used concept in the Generalised Linear Model (GLM) literature, and is defined as the function that relates the linear predictor $x\theta$ to the conditional expected value (Ramalho *et al.*, 2011):

$$\mu = E(y|x), \text{ i.e. } h(\mu) = x\theta \qquad (7)$$

The quasi-maximum likelihood estimation (QMLE) procedure was applied to obtain robust estimators of the conditional mean parameters developed above by using STATA Version 10 software (STATA Corp, 2010).

A number of farm-specific socio-economic characteristics were used as regressors to identify the determinants of PTE and SE. These are farmers' experience in years (V_1), subsistence pressure proxied by number of family members in the household (V_2), educational level of the farmer (V_3), and a set of dummy variables to identify the following: main occupation is farming (V_4), extension contact (V_5), training received (V_6), credit received (V_7), gender of the farmer (V_8), marginal farms (V_9), small farms (V_{10}), Delta North (V_{11}), and Delta South (V_{12}). Choice of these variables is based on existing literature and

justification thereof (e.g. Awerije & Rahman, 2014; Gelan & Murithi, 2012; Aye & Mungatana, 2011; Coelli e*t al.*, 2002).

2.4 Study area and the data

Data used for the study were drawn from the three geopolitical zones of the Delta state of Nigeria: North, Central and South Delta. The annual rainfall in the state varies from 2,665 mm at the coast to 1,905 mm in the inner areas, with average temperature range from 30°C to 34°C. The major food crops grown in Delta state are cassava (leading producer), yam, plantain, maize, and vegetables (MANR, 2006).

Primary data were collected from farmers/processors in the Delta State. The selection of respondents was based on two criteria. Firstly, three senatorial geographical zones in the Delta state were purposively selected. These are North, South and Central Delta regions. Second, Annual Development Program (ADP) Cell structure was used to select nine local government areas (LGAs) out of a total of 25 LGAs in these three regions was selected. Next, 35 cassava growers from each LGA were selected using a stratified random sampling procedure with cassava farm operation size as the strata. The cut-off points for farm size followed the nationally defined categories (Apata *et al.*, 2011). These are: marginal farms –upto 1.00 ha; small farms – 1.01 to 2.00 ha; medium farms – 2.01 to 10.00 ha and large farms – >10.01 ha. This provided a total of 315 cassava farmers as the sample for the study. Details on input and output data on cassava production and processing were recorded in addition to key demographic and socio-economic information from each farm household. However, only 278 farmers also processed their CRT into gari which therefore formed the final sample. The survey was conducted during September to December, 2008.

3. Results and discussion

The summary statistics of the sample farms are presented in Table 1. The average farm size is 2.07 ha with high proportion of small farms[1]; average level of completed schooling is 6.84 years; average farming experience is 16.3 years; 36% of farmers had extension contact in the past one year and only 10% received any training.

3.1 Pure technical and scale efficiency of cassava production system

As depicted in Figure 1, the first stage is the production of CRT which is the intermediate output (Z_1) obtained by using inputs of land, labour, fertiliser, and seed (X_1, X_2, X_3, and X_4). The second stage is the processing of CRT into gari (Y_1) using CRT (Z_1), processing labour (i.e. washing, peeling, grating, fermenting, drying and frying) (X_5) and other materials inputs (e.g. firewood, fuel, etc.) (X_6). Therefore, efficiency scores in the first stage measure performance of producing CRT, second stage scores measure performance of processing gari; and overall scores measure performance of growing CRT to produce the final product gari, which is a value added product.

Table 2 presents the distribution and summary statistics of PTE and SE for both sub-stages and overall production system of cassava[2]. It is clear from Table 2 that the efficiency level is lower in the production stage than the processing stage. The mean PTE of CRT production is 0.41 whereas for processing gari is significantly higher at 0.55 ($p<0.01$) leading to overall PTE of the system at 0.43. The implication is that CRT and gari production can be increased by 59% and 45% from its present level by reallocation of resources which is substantial. Seventy-nine percent of the total farmers are producing CRT at the PTE <0.50 whereas for processing cassava the figure is 48%. The variability in PTE scores is much higher in stage 1.

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[1] There is only one farm with cultivated land >10 ha. Therefore, the medium and large farms are grouped as one category.

[2] We did not report TE under CRS, which is a product of PTE and SE, as we are interested in actual level of pure technical and scale efficiencies of these farmers/processors at each stage of production.

Table 1. Definition, measurement and summary statistics of the variables (per farm)

Variables	Definition	Mean	Standard deviation
Outputs			
Intermediate output (CRT)	kg of cassava root tuber produced	11906.71	11363.330
Final output (Gari)	kg of gari processed	5293.24	6748.479
Inputs			
Farm size	Area under cassava production in hectare	2.07	1.731
Fertiliser	Kg of all fertilisers	97.45	181.992
Production labour (CRT)	Person days	244.08	258.772
Processing labour (gari)	Person days	120.40	162.078
Stem cuttings	kg	119.66	261.005
Other input costs	Naira	27269.49	38551.200
Socio-economic factors			
Education	Completed years of schooling	6.84	4.841
Subsistence pressure	Number of family members	5.86	3.311
Experience	Years engaged in farming	16.33	11.708
Delta Central	Dummy (1 if Central, 0 otherwise)	0.30	--
Delta South	Dummy (1 if South, 0 otherwise)	0.35	--
Delta North	Dummy (1 if North, 0 otherwise)	0.35	
Main occupation	Dummy (1 if farmer, 0 otherwise)	0.84	--
Extension contact	Dummy (1 if had extension contact in the past one year, 0 otherwise)	0.36	--
Credit received	Dummy (1 if had received credit, 0 otherwise)	0.31	--
Training received	Dummy (1 if had received training, 0 otherwise)	0.10	--
Marginal farms	Dummy (1 if cultivated area up to 1.00 ha, 0 otherwise)	0.10	--
Small farms	Dummy (1 if cultivated area between 1.01 – 2.00 ha, 0 otherwise)	0.67	--
Medium/large farms	Dummy (1 if cultivated area >2.01 ha, 0 otherwise)	0.23	--
Gender	Dummy (1 if male, 0 otherwise)	0.41	--

Note: Exchange rate US dollar 1 = 116 Naira and British pound 1= 200 Naira in 2008.

The PTE measures presented in Table 2 are quite low compared to those reported for cassava production in Nigeria, where TE were in the range of 0.74–0.79 (e.g. Oladeebo & Oluwaranti, 2012; Raphael, 2008; Udoh & Etim, 2007; Ogundari & Ojo, 2007). However, their estimates are based on restrictive Cobb-Douglas stochastic frontier models with relatively small sample sizes, which may be a source of difference.

Table 2. Distribution of efficiency scores of cassava production and processing

Variables	Production stage (CRT production)		Processing stage (Gari processing)		Whole cassava production system (Gari output, final product)	
	Pure Technical efficiency	Scale Efficiency	Pure Technical efficiency	Scale Efficiency	Pure Technical efficiency	Scale Efficiency
Efficiency range						
Upto 50%	78.80	7.60	47.80	2.20	76.30	8.60
51 – 60%	6.80	2.50	26.60	4.30	6.50	5.80
61 – 70%	6.40	9.40	8.60	4.30	6.10	7.90
71 – 80%	2.20	6.80	6.50	9.40	2.90	3.30
81 – 90%	0.40	19.40	2.90	25.30	0.70	15.80
91 – 100%	5.40	54.30	7.60	54.70	7.60	58.60
Efficiency measures						
Mean score	0.41	0.84	0.55	0.87	0.43	0.84
Standard deviation	0.20	0.18	0.17	0.14	0.21	0.19
Minimum	0.08	0.04	0.34	0.21	0.16	0.09
Maximum	1.00	1.00	1.00	1.00	1.00	1.00
Returns to scale (RTS) (%)						
Increasing RTS		44.60		43.90		88.10
Decreasing RTS		50.70		53.60		9.40
Constant RTS		4.70		2.50		2.50
Number of observations	278	278	278	278	278	278

However, farmers/processors are operating at a much higher level of scale efficiency, estimated at 0.84 and 0.87 for production and processing stages and 0.84 overall. Coelli *et al*. (2002) also reported much higher level of scale efficiency of Bangladeshi rice farmers at 0.93-0.95. The distribution of RTS shows that 45% and 44% of the farmers/processors are operating at IRS in production and processing stages, respectively, implying that they can increase their farm size to reach the optimal scale. Coelli *et al*. (2002) reported that 54% of the Aman rice farmers and 31% of the Boro rice farmers are operating at IRS in Bangladesh, which is not very dissimilar to our results.

3.2 Determinants of efficiencies of cassava production system

A total of 12 variables representing farm-specific socio-economic factors were used to identify the determinants of observed technical and scale efficiencies of production and processing of cassava. Table 3 presents the parameter estimates of the fractional logit model with robust standard errors by applying QMLE.

Table 3. Determinants of technical and scale efficiencies in cassava production system (fractional logit model with robust standard errors)

Variables	Production stage (CRT production)		Processing stage (Gari processing)		Whole cassava production system (Gari output, final product)	
	Pure Technical efficiency	Scale Efficiency	Pure Technical efficiency	Scale Efficiency	Pure Technical efficiency	Scale Efficiency
Constant	0.042	0.622*	0.758***	1.065***	0.469*	0.948**
Delta North[§]	0.242*	-0.338*	0.490***	-0.084	0.500***	0.062
Delta South[§]	-0.077	-0.387*	0.112	0.078	-0.037	-0.256
Education	-0.008	0.020	0.005	-0.005	-0.002	0.041**
Main occupation[§]	-0.003	0.422**	0.014	0.152	-0.013	0.482**
Subsistence pressure	0.008	-0.038*	-0.001	-0.047**	-0.007	-0.042*
Experience	0.000	0.016**	0.001	-0.003	-0.003	0.025***
Extension contact[§]	-0.264**	-0.012	-0.331***	0.507**	-0.381***	-0.961***
Training received[§]	-0.218	0.314	-0.024	0.223	-0.249*	0.055
Credit received[§]	-0.070	0.195	0.174**	-0.183	0.055	0.163
Medium/Large farms[§]	0.129	-0.006	-0.877***	0.914***	-0.417*	-0.802***
Small farms[§]	-0.578**	1.339***	-0.866***	1.390***	-0.906***	1.271***
Gender[§]	0.032	-0.037	0.155**	-0.134	0.144	-0.273*
Model diagnostic						
Pseudo log likelihood	-126.167	-83.069	-127.203	-73.998	-125.374	-79.002
AIC	1.001	0.691	1.009	0.626	1.001	0.667
BIC	-1453.890	-1449.490	-1462.520	-1463.130	-1438.897	-1438.663
H_0: No influence of dummy variables in the model						
Chi-squared (8 df)	13.49*	15.85**	0.18	10.25	17.54**	24.80***
Number of observations	278	278	278	278	278	278

Note: *** = significant at 1 percent level (p<0.01)
       ** = significant at 5 percent level (p<0.05)
       * = significant at 10 percent level (p<0.10)
       § = dummy variables

The model diagnostics reveal that these variables jointly explain variation in farm-specific efficiency levels quite satisfactorily. A total of 32 coefficients out of 72 in six models were significantly different from zero, at least, at the 10% level. Likelihood ratio tests were conducted to check joint influence of the dummy variables in the model. The null hypothesis of no influence of eight dummy variables used in the model was strongly rejected for the production stage and whole cassava system models at least at the 10% level (see lower panel of Table 3). It is clear from Table 3 that, in general, these factors exert differential effect on different measures of efficiency at each stage and overall.

Education and farming experience significantly improve scale efficiency overall and the latter improves scale efficiency at the production stage. Aye & Mugatana (2011) and Seyoum *et al.* (1998) demonstrated significant role of farmers' education in raising technical efficiency in Nigeria and Ethiopia. Therefore, significant positive influence of education to enable cassava farmers/processors to operate at an optimal scale is encouraging.

Also, farmers who identified their main occupation as farming are scale efficient overall and at the production stage. Gender gap exists in performance measures. Male farmers are technically more efficient at the processing stage but overall scale inefficient relative to female operators. Subsistence pressure significantly reduces scale efficiency throughout. The interpretation is that large families with fewer working adults are not able to operate at an optimal scale because labour available from the family may not have the requisite experience in farming.

Extension contact exerts negative influence in most cases except SE in gari processing where the influence is positive consistent with expectation. The implication is that farmers who had extension advice are using too much of inputs and/or operating at sub-optimal scale but not achieving expected yield. Aye & Mungatana (2011) also reported significant negative influence of extension contact on technical efficiency in maize production in Nigeria. They concluded that the extension services in Nigeria in general have not been effective, especially after the withdrawal of the World Bank funding from the Agricultural Development Project, which is the main agency responsible for extension services. However, the significant positive influence of extension contact in improving SE in cassava processing stage is encouraging. Training significantly negatively influences PTE overall. The reasons may be that the type of training which the farmers received are either not relevant or not specifically on cassava production and only 10% of the farmers have actually received any type of training in the sample.

Medium/large farms are both technically and scale inefficient overall but scale efficient at the processing stage relative to marginal farmers (whose effects are subsumed in

the intercept term). On the other hand, small farms are scale efficient but technically inefficient in all the models. The implication is that small farms are operating at optimal scale but using too much of input and not achieving expected yield relative to marginal farmers (whose effect is subsumed in the intercept term). This is because small individual farms on average utilise the two inputs (land and labour) more efficiently than the large corporate farms, and for any given bundle of inputs the small farms produce on average more than the large farms as evidenced in Moldova (Lerman & Sutton, 2006). In our study, marginal farms seems to be relatively more technical efficient than the small and medium/large farms. These findings imply that inverse size-PTE and size-SE relationships exist in the cassava production system in Nigeria, where marginal farms and/or small farms fare better relative to medium/large farms. Niroula & Thapa (2005) noted that an inverse relationship between farm size and productivity is prominent in areas where farming practice is labour intensive because, for the large farms, high level of labour costs deters them to use hired labour to optimal levels, which is consistent with our findings.

Farmers located in the northern regions are technically efficient throughout but scale inefficient at the CRT production stage. The reasons may lie with respect to differences in the regional features (e.g. soil conditions, topography, and weather) and market conditions (e.g. input prices, timely availability, market infrastructure, and market competition).

4.   Conclusions and policy implications

The present study examines pure technical and scale efficiency levels of cassava production system by analysing its sub-processes, i.e. production and processing stages of 278 cassava farmer/processors from three regions of Delta State, Nigeria, by applying Two-Stage DEA approach and also identifying their determinants using a fractional logit model.

Lower level of PTE at both stages indicate substantial potential to improve CRT and gari output by 59% and 45%, respectively, by reallocation of resources. Although SE is relatively high at both stages, scope still exists to improve CRT and gari output up to 16% and 13%, respectively, by adjusting farm operation size. This is reinforced by the finding that

44.6% and 43.9% of the farmers/processors are operating at increasing RTS in production and processing stages, implying that they should increase their land area to reach optimal scale.

Decomposition of technical efficiency measures into PTE and SE allowed to identify differential effects of the socio-economic factors on these scores at each stage and overall level. Overall, education and experience improve SE. Extension contact negatively affects efficiencies throughout except SE at the processing stage. Inverse size-PTE and size-SE relationship hold in cassava production system in Nigeria, i.e. medium/large farms are inefficient although small farms are also technically inefficient relative to marginal farms. Gender gap exists in performance where male farmers are technically efficient at the processing stage, but scale inefficient overall. A total of 48.9% of the total sampled farmers are women implying that cassava is no more a women's crop. The yield of cassava root tuber is estimated at 7888.9 kg/ha and 7543.6 kg/ha for male and female farmers, respectively indicating higher productivity by male farmers. Also, the quantity of gari processed by male and female farmers is estimated at 5353.61 kg and 4192.2 kg, although the differences are not statistically significant (Awerije, 2014). Farmers located in northern region are more technically efficient as those located in the central and southern region. The reasons for such differences may lie with respect to differences in the regional features (e.g., soil conditions, topography, weather, and other unknown factors) and/or market conditions (e.g., input prices, timely availability, market infrastructure, market competition, etc.) (Awerije & Rahman, 2014).

The policy implications point towards investment in education targeted at the farmers/processors which will improve their ability to optimise operation size of the whole

cassava production system. The extension services also need to be revitalised so that they not only support scale efficiency at the processing stage but contribute to improving efficiencies at every stage of the cassava production process. This would require investment in developing capacity of the extension workers so that they can effectively serve to benefit farmers/processors. Also, measures are needed to target farmers located in Delta Central and Delta South to support them to overcome low level of efficiency relative to Delta North. This may take the form of providing infrastructural and marketing support to bring them at par with the facilities and opportunities available for farmers in Delta North. Although the policy options are challenging, effective implementation of these measures will increase production of cassava that could contribute positively to agricultural growth in Delta State, Nigeria.

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