Economic Efficiency of Cassava Production in Nimba County, Liberia: An Output-Oriented Approach

Kollie B. Dogba, Willis Oluoch-Kosura, Chepchumba Chumo

***Abstract*—**Cassava can be cultivated for food and income purposes. In Liberia, many of the agricultural households plant Cassava. Nimba is one of the counties with intensive cassava-cultivating farmers. The North-eastern County borders the Republics of Guinea and Cote D'Ivoire. Many of the Cassava farmers in Nimba cultivate cassava for sustenance purposes.

Emerging crop trading opportunities trigger the concerns to assess the effectiveness of existing cassava technology to stimulate production for higher income and economic development. However, there is dearth information on the level of cassava production efficiency in Liberia. Therefore, the study sought to examine the economic efficiency of cassava production to farmers in Nimba using an output-oriented approach.

A multi-stage sampling technique was employed to generate a sample for the study. From 216 cassava farmers, data related to on-farm attributes, socio-economic and institutional factors were collected. The stochastic frontier models, using the Translog functional forms, of production and revenue, were used to determine the level of revenue efficiency and its determinants.

The result showed that most of the cassava farmers are male (60%). Many of the farmers are either married, engaged or living together with a spouse (83%), with a mean household size of nine persons. Farmland is prevalently obtained by inheritance (95%), average farm size is 1.34 hectares, and most cassava farmers did not access agriculture credits (76%) and extension services (91%). The mean cassava output per hectare is 1,506.02 kg, which estimates an average revenue of L$23,551.16 (Liberian dollars). Empirical results showed that the revenue efficiency of cassava farmers varies from 0.1% to 73.5%; with the mean revenue efficiency of 12.9%. This indicates that on average, there is a vast potential of 87.1% to increase the economic efficiency of cassava farmers in Nimba by improving technical and allocative efficiencies. For the significant determinants of revenue efficiency, age and group membership had negative effects on revenue efficiency of cassava production; while farming experience, access to extension, formal education, and average wage rate has positive effects. The study recommends the setting-up and incentivizing of farmer field schools for cassava farmers to primarily share their farming experiences with others and to learn robust cultivation techniques of sustainable agriculture. Also, farm managers and farmers should consider a fix wage rate in labor contracts for all stages of cassava farming.

***Keywords*—** Economic Efficiency, Frontier Production, and Revenue functions, Liberia, Nimba County, Output-Oriented, Revenue Efficiency.

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I. Introduction

In Liberia, the agriculture sector is the main source of livelihood. The sector contributes 25.8% to GDP accounts [1]. More than two million people are directly employed in the agricultural sector; while seventy-six percent of agricultural households cultivate cassava [2]. Liberia's agricultural policies are aimed toward the achievement of sustainable agriculture to meet domestic food production, increase the farm income of farmers, enhance trade of agriculture commodities and provide decent employment, especially to vulnerable groups.

Cassava is one of the paramount staples consumed and the highest food crop been produced in Liberia [3]. With a mean output range of 6-7 metric tonnes, cassava output is short of domestic demand and lower than the West Africa regional range of 10-18 metric tonnes [4]. Current food import to Liberia accounts for 24% of total imports with a worth more than US$91 million dollars [5].

The demand for cassava as an industrial input is facilitating emerging markets in Asian economies, an opportunity for sub-Sahara African countries to engage in cassava trade for economic development [6]. As a beneficiary to China's preferential free trade agreement to developing countries, Liberia benefits 99% tariff-exemption on exports to China: an opportunity to optimize trade of cassava tubers and cassava products to one of the largest cassava consuming markets of raw and processed cassava tubers [7].

Despite this opportunity, there is a dearth of information concerning the efficiency of Cassava Production in Liberia. Hence, this study seeks to assess the economic efficiency of cassava production from an output-oriented perspective. Moreover, the study endeavors to assess determinants of economic efficiency. Optimizing economic efficiency of cassava production is expected to contribute to domestic food security, enhance trade for employments along the cassava value chain and sustainable agriculture-led development.

II. Materials And Methods

A. *The study area*

The study was conducted in Nimba County, the north-eastern county which is the second populous county with 462,026 residents [8]. With a size of 2,300 sq. km, the county shares international borders with Guinea and Cote D'Ivoire; has an average rainfall between 12.5mm to 300mm per year, and contains the largest portion of agricultural latosol in the country [9]. The county contains one of the six agriculture clusters: The Nimba cluster, within which farmers prioritized rubber, cocoa, rice, vegetables, aquaculture and cassava productions [10]. This agriculture cluster with more than 26,530 farm households contributes the highest cassava output (of 26 percent) to the aggregated cassava output of Liberia, compared with the outputs of other counties [2,3].

B. *Sampling and Data Collection*

The study employed a multi-stage sampling technique. In the first, the purposive sampling procedure was used to select Nimba because of the intensiveness of cassava cultivation in the county. In the second stage, purposive sampling was used to select four specific districts where cassava farming is concentrated. In the third stage, a systematic sampling procedure was used to select cassava farmers from available farmers' list in the district. Kothari's estimator of a finite population [11] was used to determine the sample size. Between May – June 2019, primary data on-farm attributes, socio-economic and institutional factors concerning cassava production were collected from 216 farmers using structured questionnaires and schedules.

To analyze the data, descriptive statistics of means and frequencies were used to observe the institutional, socio-economic and farm attributes of cassava farming. Stochastic Frontier Models of Translog production and revenue functions were used to determine the revenue efficiency of cassava production in Nimba.

C. *Theoretical & Analytical Frameworks*

Efficiency concept evolved when Debreu [12] and Koopmans [13] sought to understand production productivity and the performance of the economy toward Pareto optimality. Koopmans [13] introduced the technical efficiency concept to explain the inefficiency of physical resources, production firms, and organizations, while Debreu [12] used the coefficient of resource utilization to measure the efficiency of the economy. On these foundational works [12,13], Farrell used agricultural data to propose an econometric procedure to measure economic efficiency [14]. Farrell's parametric procedure decomposed the measure of economic efficiency into technical efficiency [the capacity of production unit to attain the maximum output from available inputs/services] and price efficiency [the ability of production unit to use optimal resources based on economic allocations of the cost/price of inputs/output] at a given technology level. Farrell's work [14] set the foundation for Schmidt [15], Aigner [16], Meeusen [17], and Lovell [18], to further explore support to the parametric measurement of efficiency. Yet, other authors, including Afriat [19], Fare [20], and Charnes [21], criticized the many priori assumptions of the parametric measurement of efficiency, while proposing optional deterministic possibilities to measure economic efficiency. According to Coelli [22], these two compelling concepts of parametric and non-parametric (deterministic) procedures formed the basis of a researcher's choice to use either the Stochastic Frontier Analysis [SFA] or the Data Envelopment Analysis [DEA]. The SFA incorporates statistical errors, and evaluates viable parametric confidences for inference, even though they contain stocky assumption with and intricate computations [22,23]; while the DEA recognizes slacks, and uses easier programming procedures to estimate the efficiency, though derived standard errors are plainly unreliable for inferential statistics [22,24].

A firm is economically efficient if it achieves both technical and allocative efficiency. In Fig. 1, a firm produces two products [q_1 and q_2] using a resource set x_1 on the assumption of a constant return to scale. The curve SS' is the production possibility frontier (PPF), RR' is the iso-revenue function and O is the origin of the Cartesian plane. At the present output level of point P, and PPF is the ideal optimal boundary on which the firm can produce the highest combined outputs. To become technically efficient, the rational firm seeks to optimize its production output of q_1 and q_2 from point P to point Q which lie on the PPF. Hence, the Technical inefficiency of the firm becomes the proportionate distance between the observed and the ideal production frontiers; i.e.

$$TE = OP/OQ \qquad (1)$$

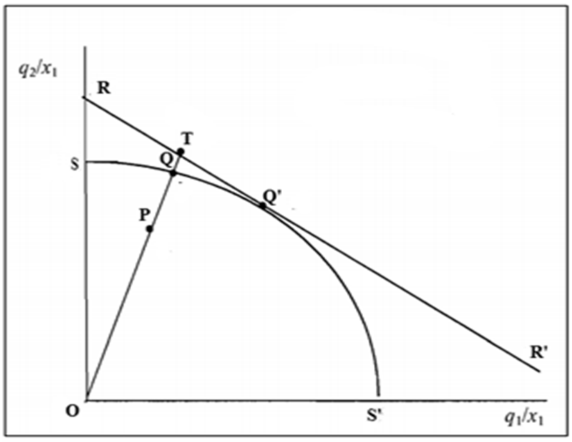

Fig. 1: Output Oriented Inefficiency Measurement
Source: Adopted from Coelli *et al. (2005)*

Assuming competitive output prices, revenue can be increased to the optimal iso-revenue point T on line RR'. Allocative inefficiency can be determined from the gap through which optimal output yield Q and the comparative output price will yield the maximum revenue on line RR'; i.e.

$$AE = OQ/OT \qquad (2)$$

To attain revenue efficiency, the firm must adjust production within the scope of its frontier to the ideal frontier, from P to Q, while also considering output prices to attain the maximum revenue at point Q' from the allocation of products in the output markets. Hence, the economic inefficiency index measures the composite gap needed for a firm producing at output level P to attain both technical and allocative efficiency at point Q'; i.e.

$$RE = TE * AE = \frac{OP}{OQ} * \frac{OQ}{OT} = OP/OT \quad (3)$$

Technical, allocative and economic efficiencies are expressed in either decimal (interval of 0 to 1 inclusively) or by percentage with a value of 1 indicating full efficiency.
Efficiency models estimations procedures include Maximum likelihood estimation (MLE), Ordinary least square (OLS) or corrected Ordinary Least squares procedures (COLS); however, the ML Estimation is preferred because it derives unbiased and consistent estimates with asymptotically normal distribution properties for large samples models [22,23]

D. Model Specification And Estimation

From statistical testing of the Cobb-Douglas and Trans-log functional forms on the data, the Translog functional form was adopted to estimate the production and revenue functions of cassava production because of its statistical superiority. The stochastic cassava technology is presented as:

$$Y_i = AX_i^{\beta_i} \ldots X_k^{\beta_k} e^{((0.5\beta_{ij})((\ln X_i)^2(\ln X_i)(\ln X_j)(v-u))} \quad (4)$$

However, transforming non-linear and curvilinear models to linear equivalents provide easier understanding and better analyses [25]. Hence, the model was linearized to:

$$\ln Y_i = A + \sum_{i=1}^{M} \beta_i \ln(x_i) + 0.5 \sum_{i=1}^{M}\sum_{j=1}^{M} \beta_{jk} \ln(x_i)\ln(x_j) + (v_i - u_i) \quad (5)$$

where Yi is Cassava Output of the i[th] farmer, X_i to X_M are inputs, A = β_0 accounts for technology homogeneity, $\beta_1 \ldots \beta_k$ are parameters for X_1 to X_M inputs, β_{jk} are parameters for squares and symmetries of X_jX_k inputs, ln is the natural logarithm conversion of the predicted exponential growth, v_i is a two-side normal error term with mean zero and constant variance (error due to model specifications, measurement and other characteristics outside the control of the farmers), and u_i is a one-side truncated normal error from cassava production: the inefficiency effect from cassava farms and farmers.
Because the concept of the revenue frontier underlines maximizing revenue from the output level, the revenue function is modeled after a similar manner as the production function, but with the inclusion of competitive output market prices [26].

Hence, the stochastic revenue function of cassava production is modeled as follow:

$$\ln R_i = \alpha_0 + \sum_{i=1}^{N} \alpha_i \ln(x_i) + 0.5 \sum_{i=1}^{N}\sum_{j=1}^{N} \alpha_{jk} \ln(x_i)\ln(x_j) + \alpha_8 \ln p_y + (v_i - u_i) \quad (6)$$

where $\ln(R_i)$ is the maximum revenue of the i[th] farmer producing cassava, X_i to X_N are inputs, P_y is the price per output (kg), α_0 accounts for fixed Revenue, α_i to α_N accounts for varied parameters of Xi to Xj inputs estimated in the revenue function. α_{jk} indicate parameters for squares and symmetries of the revenue function, α_8 accounts for parameter estimate for output price, ln is the natural logarithm conversion of the predicted exponential growth, *vi* is a two-side normal error term with mean zero and constant variance (error in the specification of the revenue function, and other market factors outside the of the farmers) and *ui* is a one-side truncated normal error from revenue generated from cassava production (the price inefficiency resulting from inefficient cassava markets). The inputs used in the production and revenue functions are land (farm size), labor efforts (from male and female laborers), cassava stem/cuttings, and farm tools (machete and hoes).
The efficiency model for production and revenue functions are both models as follow:

$$TE_i, AE_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + \delta_9 Z_9 \ldots \delta_n Z_n + v_i \quad (7)$$

Where, TE_i = technical efficiency, AE_i = allocative efficiency, $\delta_1 \ldots \delta_n$ are the parameters estimates, v_i is the stochastic error terms (normal two-sided) as discussed above, Z_1 = farmer's age, Z_2 = Gender, Z_3 = Farming Experience, Z_4 = Formal education, Z_5 = Household Size, Z_6 = Group membership, Z_7 = Access to Credit, Z_8 = Access to extension contact, Z_9 = Access to Market and Z_9 = other variables.

By the one-step Maximum likelihood estimation procedure on an assumption of truncated normal distribution. The stochastic production frontier model was estimated simultaneously with the inefficient models to determine the TE; while the stochastic frontier revenue frontier was jointly estimated with the inefficiency function to determine the output-AE. Economic efficiency was derived from the product of Technical and Allocative Efficiency.

III. Results And Discussion

Descriptive statistics for variables of the study are presented in TABLE I. The one-step joint Maximum Likelihood Estimates from equations (5), (6) with equation (7) are presented in TABLE II. Efficiency indices determined after estimation procedures are listed in TABLE III, while determinants of economic efficiency derived from the technical and output-allocative efficiencies are presented in TABLE IV.

From the result in TABLE I, an average cassava farmer is 44-year-old. Most cassava farmers in the study area are male (60%), who are either married, engaged or lived together with a spouse (83%), in a mean household of nine persons. With a mean experience of 10 years, many farmers (73%) principally cultivated cassava for sustenance; even though, almost all of these farmers (93%) depend on agricultural activities to generate income. Many of the cassava farmers (95%) cultivate cassava on land inherited. Many farmers do not have any farm group membership. Hence, there are challenges for many of the cassava farmers to access agricultural credits (76%), and extension services (91%).

The mean cassava output is 1,506.02 kg from an average farm size of 1.34 hectares. This indicates that many of the farmers are small-scale farmers based on Rapsomanikis [27] classification of smallholder farmers by land use. The mean output price and revenue of cassava farmers are L$21.15 and L$26,030.59 respectively.

From the estimation of the stochastic production and revenue models in TABLE II, significant production factors are land (at 5%), joint labor efforts (interactions) from male and female workers (at 5%), and the stem and hoe interactions (at 10%), and the importance revenue factor is output price (at 1%).

The factors of production have a negative impact on the level of cassava production in the study area. This signals farmers' consideration to diversify land-use by cultivating cassava and other crops on the existing farmland or to reduce the portion of land allocated to cassava in an approach to optimize the cassava cuttings planted on the farm. Also, jointly recruiting efforts (of male and female laborers) for cassava production does not support production output. Farmers should consider labor recruitment based on two indicators: gender-specificity to a particular production task (whether for land preparation, planting, or weeding), and the nature of tool to consider during specific stages of the production chain. For the latter, consideration to substitute the use of hoe with another planting tool (say machete) during the planting of cassava cuttings/stems. Cassava output price positively increases revenue. This indicates that in markets where cassava demand is higher, farmers have an opportunity to increase income from cassava through higher ca output prices.

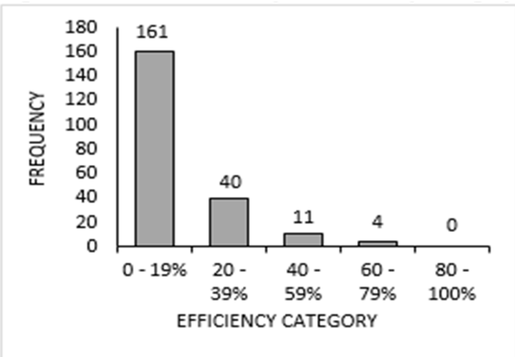

Fig. 2: Revenue Efficiency of Cassava farmers

From the determination of efficiency indices in TABLE III, the mean revenue efficiency of cassava farmers is 12.9 percent, derived from 31.7 percent technical efficiency, and 29.7 percent output-allocative efficiency of cassava production. The range of the Revenue efficiency lies between 0.1 to 73.5 percent with many of the farmers (74%) attaining revenue efficiency within the lowest category of 0-19% (Fig. 2). This indicates that there is an enormous gap of 87.1 percent to increase the Revenue efficiency of cassava farmers in Nimba County. By improving technical and output-allocative efficiency, cassava farmers can achieve optimal Revenue efficiency.

Estimates of determinants spurring technical and allocative efficiencies to optimize Revenue Efficiency are presented in TABLE IV. These factors, the determinants of the Revenue Efficiency of cassava production in the study area are discussed below:

Age – The estimates of age is positive and significant at 5% toward input-output maneuvering. The positive sign indicates increasing technical inefficiency effects as a farmer gets older (an implication that revenue efficiency reduces as a farmer gets older). This result emphasizes the outlook that older farmers become less energetic to the intensive production activities of cassava. Hence, an option to employ energetic labor is pertinent to realize higher output and revenue efficiency. The negative age effect is in line with similar studies of Khan, Saeed and Maina [28,29], but contrary to a study by Nginyangi [30] where age had a positive effect. The unsettling trend indicates that there is a relative age-productivity peak as a farmer gets older [31]. Such a threshold is not yet established for cassava farmers in Liberia. Even though the study provides a trend, the age-productivity threshold for cassava farmers seems to be at an age lower than the mean age established by this study.

Source of Income – At a 5% statistical significance, the variable has a negative effect on the technical inefficiency of cassava production. This connotes that, as many cassava farmers rely on agricultural activity to generate income, the revenue efficiency of cassava production will be positively impacted. The ramification is that when cassava farmers become reliant on agricultural activities to generate income, cassava production could eventually be considered an enterprise. By this move, the farmer can used inputs between farms to minimize resource waste and production defeats in order to optimize production and sales.

Formal Education – Formal education has a 10% statistical negative effect on output-allocative inefficiency, implying a positive effect on revenue efficiency. This corroborates the results of similar efficiency studies of Lema [32] and Nginyangi [30], that higher acquisition of formal education enhances the ability of the farmer to make "better and timely" market decisions. However, the result diverts from a similar study's result of Mutoko [33], where maize farmers that obtained higher education tended to abandon farming activities for non-farm activities to generate greater income.

Group Membership – contrary to expectation, group membership has positive effects on allocative inefficiency at the statistical relevance of 1%. This implies that revenue efficiency may reduce when a farmer seeks to become a member of a farming group. This could be due to opportunism and free rides which the few members seek, and the spillover effects which burdens group members to pay for market information that non-members also benefit from without a cost.

Average Wage for Activity – The estimate of wage has a negative effect on allocative inefficiency, connoting that revenue efficiency increases when the wage is paid under futures. Labor as a key factor along with the production activities of land preparation, planting, and weeding, have varying specificity and cost. Hence, increasing future contracts on an average wage for labor helps a farmer save time and efforts during labor mobilization, negotiation, and payment.

Farming Experience – With a statistical significance of 1%, farming experience has negative effects on both technical and output-allocative inefficiencies. The implication is with more experience in cultivating cassava, a farmer can rectify some of the defects in input-output engineering and find new ways to access information about markets [inputs and output]. This result aligns with results of Abdul-Kareem and Sahinli [34], Adeyemo, [35], and Ogunleye [36], that farming experience improves the efficiency and profitability of cassava production; but it differs with Maina's result [29] that membership in farming groups linked farmers to credits and support services to improve inputs and increase efficiency.

Access to Extension – At a 5% significance level, the estimates of access to extension services have negative relationships to both technical and allocative inefficiencies. This implies that farmers accessing more extension services tended to learn contemporary methods for reducing production inefficiency. The result also alludes that extension services link farmers to economic agents and markets: an opportunity which gives farmer advantage along the cassava value chain. The results conform to similar studies related to coffee [32], potatoes [37], and maize [33].

IV. CONCLUSION

The study determined the economic efficiency of cassava production using an output-oriented approach. Descriptive statistics were generated to observed farm resources, institutions and socio-economic attributes of cassava farmers in Nimba County, Liberia. From data collected from 216 farmers, the Stochastic Frontier Production and revenue models were estimated using the joint Maximum Likelihood Estimation procedure to estimate the technical and output-allocative efficiencies. Land, labor efforts (of male and female interactions) and StemHoe interactions are the significant production factors to cultivate cassava in Nimba, and cassava output price is paramount to cassava income. There is a revenue efficiency gap of 87.1 percent to be achieved from the current mean revenue efficiency level of 12.9 percent. The analysis of efficiency categories showed a decreasing trend of efficiency from lower to higher categories. Seventy-four percent (74%) of the cassava farmers fall within the lowest efficiency category of 0-19%; while none of the farmers have efficiency in the highest category of 90-100%. The study concludes that farming experience, access to extension, formal education, and source of income are factors that positively influence revenue efficiency; while age and group membership impede progress to revenue efficiency.

The study recommends that policymaker should strategize to attract more young people into cassava cultivation, subside and expand the access of extension services on farmer field schools own by government, and to encourage crop diversification especially food crops: cassava and rice for increase farm income, sustenance, and trade for economic development.

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APPENDIX

TABLE I
DESCRIPTIVE STATISTICS OF FARMER CHARACTERISTICS AND VARIABLES USED IN THE FRONTIER MODELS

Variable	Mean	Std. Dev.	Min	Max
Cassava Output (kg)	1,506.02	1,413.2	75	10,000
Farm size (in hectare)	1.34	1.1	0.2	12.1
Machete (pcs)	3.64	2.2	0	22
Stem (bundles)	43.63	30.8	3	200
Digging Hoe (in pcs)	4.19	3.0	0	32
Male Labor (man-day)	22.66	15.8	0	80
Female Labor (man-day)	20.78	13.8	0	65
Age of farmer (years)	44.20	13.4	16	80
Farming Experience	10.08	8.3	1	48
Household Size	9.23	4.0	3	28
Formal Education	6.67	5.3	0	19
Farm to markets (km)	5.59	5.1	1	42
Output price (L$ per kg)	21.15	15.6	4	90
Revenue (L$ per output)	26,030.59	24,254.2	900	156,250

Variables	Freq.	Percent
Gender		
Female	86	0.4
Male	130	0.6
Marital Status		
Not Single	180	0.83
Single	36	0.17
Farm's Motivation		
Food	160	0.74
Income	56	0.26
Access to Extension		
No	197	0.91
Yes	19	0.09

Variables	Freq.	Percent
Access to Credits		
No	165	0.76
Yes	51	0.24
Farm group membership		
None	175	0.81
One	32	0.15
Two	9	0.04
Main source of Income		
Farm activity	201	0.93
Non-farm activity	15	0.07
Source of farmland		
Inheriting Land	206	0.95
Buying Land	3	0.01
Renting/ others	7	0.03
Age Group		
Under 25 years	7	0.03
25-34 years	48	0.22
35-44 years	63	0.29
45-54 years	45	0.21
55-64 years	30	0.14
Above 64 years	23	0.11

TABLE II

MAXIMUM LIKELIHOOD ESTIMATES FOR CASSAVA FARM USING THE TRANS-LOG PRODUCTION AND REVENUE FUNCTIONS

Variable	Estimates	Std. Err.
Trans-log Production function: Dependent Variable = Ln Cassava Output		
Constant	7.17***	1.8
LnFarmland	-1.44**	0.72
LnStem	-0.2	0.66
LnMachete	0.3	0.78
LnHoe	-0.89	0.85
LnMalelabor	0.56	0.5
LnFemlabor	0.58	0.6
LnFarmland•LnFarmland	0.04	0.29
LnStem•LnStem	0.13	0.2
LnMachete•LnMachete	0.01	0.39
LnHoe•LnHoe	0.43	0.32
LnMalelabor•LnMalelabor	-0.12	0.13
LnFemalelabor•LnFemalelabor	-0.01	0.14
LnlandStem interaction	0.21	0.2
LnlandMachete interaction	-0.15	0.23
LnlandHoe interaction	-0.05	0.3
LnlandMalelabor interaction	0.22	0.14
LnlandFemalelabor interaction	0.05	0.16
LnStemMachete interaction	0.2	0.21
LnStemHoe interaction	-0.40*	0.22
Trans-log Production function: Dependent Variable = Ln Cassava Output		
LnStemMalelabor interaction	0.07	0.13
LnStemFemalelabor interaction	-0.02	0.13
LnMacheteHoe interaction	0.15	0.25
LnMacheteMalelabor interaction	-0.23	0.2
LnMacheteFemalelabor interact.	-0.05	0.2
LnHoeMalelabor interaction	0.23	0.19
LnHoeFemalelabor interaction	0.2	0.21
LnMalelaborFemalelabor intera.	-0.20**	0.1
Revenue function: Dependent variable = Ln Revenue		
Variable	Estimates	Std. Err.
Constant	8.84***	0.45
LnFarmland	0.12	0.11
LnStemHoe	0.04	0.03
LnMalelaborFemalelabor	0.02	0.02
LnAverage output price	0.63***	0.11

*,**,*** indicate 10%, 5%, and 1% significance respectively

TABLE III

ESTIMATION RESULT OF TECHNICAL, OUTPUT ALLOCATIVE AND REVENUE EFFICIENCY DERIVED FROM THE SFA MODELS

Efficiency Level	TE Freq.	Output-AE Freq.	RE Freq.
0 - 19%	81	83	**161**
20 - 39%	67	72	**40**
40 - 59%	43	43	**11**
60 - 79%	23	17	**4**
80 - 100%	2	1	**-**
Obs.	216	216	**216**
Mean	0.317	0.297	**0.129**
Std Dev.	0.206	0.186	**0.150**
Minimum	0.029	0.032	**0.001**
Maximum	0.983	0.839	**0.735**

TABLE IV:
DETERMINANTS OF INEFFICIENCIES DERIVED FROM THE PRODUCTION AND REVENUE FUNCTIONS

Technical Inefficiency Model:		
Variable	Estimate	Std. Err.
Constant	2.82***	0.69
Age	0.01**	0.01
Farming experience	-0.05***	0.01
Farm to market (km)	0	0.01
Access to Extension (1 = yes)	-0.66**	0.29
Group membership (1 = yes)	0.22	0.14
Access to credits (1= yes)	-0.08	0.15
Source of Income (1=farm act.)	-0.80**	0.35
Source of Labor for Planting:		
Farming group	25.25	78.77
Hired labor	-0.59**	0.26
Sigma_u	0.67***	0.09
Sigma_v	0.34***	0.1
Lambda	2.00***	0.18
Gamma	0.8007	
Likelihood Ratio Statistics (H_0 = -225.35, H_1 = -224.36)	61.970***	df = 12
Output-Allocative inefficiency Model:		
Variable	Estimate	Std. Err.
Constant	4.51***	1.39
Age	0.01	0.01
Formal Education	-0.17*	0.09
Farming experience	-0.03***	0.01
Farm to Market	-0.01	0.01
Access to Extension (1=yes)	-0.68**	0.28
Group Membership (1=yes)	0.35***	0.13
Access to credits (1= yes)	-	-
Log Labor wage	-0.61***	0.21
Log Hoe price	0.19*	0.1
Sigma_u	0.69***	0.1
Sigma_v	0.41***	0.12
Lambda	1.68***	0.21
Gamma	0.738	
Likelihood Ratio Statistics (H_0 = -274.61, H_1 = -224.74)	59.72***	df = 11

*,**,*** indicate significance level at 10%, 5% and 1% respectively

REFERENCES

[1] Liberia CB of. Central Bank of Liberia Annual Report for 2017. 2017.
[2] LISGIS-RL. Household Income and Expenditure Survey 2016 Statistical Abstract. Monrovia, Liberia; 2017.
[3] Ministry of Agriculture, Republic of Liberia. Production estimates of Major Crops and Animals - 2008. Monrovia, Liberia; 2009.
[4] Coulibaly ON, Abdoulaye T, Arinloye D-DAA, Vodouhe F. Regional Cassava Value Chains Analysis in West Africa: Regional Summary. 2014;(JANUARY):49.
[5] Liberia CB of. Central Bank of Liberia Annual Report for 2018. 2018.
[6] Nweke FI, Spencer DSC, Lynam JK. The Cassava Transformation. Africa’s Best Kept Secret. Michigan State University Press, East Lansing, MI. Michigan State University Press • East Lansing; 2002. 293 p.
[7] Ministry of Commerce and Industry R of L. Liberia: Ministry of Commerce and Industry Transition Report_2017 [Internet]. 2017. Available from: http://moci.gov.lr/doc/MoCI.Min.Addy.Transition.Rebranding Commerce.Final_small_1.pdf
[8] LISGIS. Republic of Liberia 2008 National Population and Housing Census: Final Results. Popul (English Ed. 2009;(May):1–5.
[9] Government of Liberia (b). Nimba County Development Agenda, Republic of Liberia. 2012.
[10] Zinnah MM. Liberia Agriculture Transformation Agenda_Six Agro-clusters Identified In Liberia. Monrovia, Liberia: Ministry of Agriculture, Liberia; 2016.
[11] Kothari CR. Research Methodology: Methods and Techniques [Internet]. New Age International Publishers; 2004. 418 p. Available from: http://dspace.utamu.ac.ug:8080/xmlui/bitstream/handle/123456789/181/Research Methodology - Methods and Techniques 2004.pdf?sequence=1
[12] Debreu G. The Coefficient of Resource Utilization [Internet]. Vol. 19, Source: Econometrica. 1951 [cited 2019 Feb 12]. Available from: https://www.jstor.org/stable/pdf/1906814.pdf?refreqid=excelsior%3A3b9856168eaab28ca543b12e39861634
[13] Koopmans CT. Efficient Allocation of Resources. Econometrica [Internet]. 1951 [cited 2019 Feb 12];Vol. 19,(No. 4):455–65. Available from: https://about.jstor.org/terms
[14] Farrell M. The Measurement of Productive Efficiency. R Stat Soc. 1957;120(3):253–90.
[15] Schmidt P, Lovell CAK. Estimating Technical and Allocative Inefficiency relative to Stochastic Production & Cost Frontiers. J Econom. 1979;9:343–66.
[16] Aigner DJ and, Chu SF. On Estimating the Industry Production Function. Am Econ Rev. 1968;58(3):531–7.
[17] Meeusen W, Van Den Broeck J. Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. Int Econ Rev (Philadelphia). 1977;18(2):435–44.
[18] Aigner D, Lovell CAK, Schmidt P. Formulation and Estimation of Stochastic Frontier Production Models. J Econom. 1977;6:21–37.
[19] Afriat S n. Efficiency Estimation of Production Functions. Int Econ Rev (Philadelphia). 1972;13(3):568–98.
[20] Fare R, Knox Lovell CA. Measuring the technical efficiency of production. J Econ Theory. 1978;19(1):150–62.
[21] Charnes A, Cooper WW, Rhodes E. Measuring the efficiency of decision-making units. Eur J Oper Res. 1978;2(6):429–44.
[22] Coelli TJ, Rao DSP, O’Donnell CJ, Battese GE. An Introduction to Efficiency and Productivity Analysis. 2nd Editio. Springer Science + Business Media, Inc; 233 Spring Street, New York; 2005. 331 p.
[23] Kumbhakar SC, Lovell C a. K. Stochastic frontier analysis. Stoch Front Anal [Internet]. 2000;69:680. Available from: http://books.google.com/books?hl=en&lr=&id=wrKDztxLWZ8C&oi=fnd&pg=PR9&dq=Stochastic+frontier+analysis&ots=L1Ptx0MJ21&sig=k1yR968QVtd1YCORupspxcLgtDs
[24] Cooper WW, Seiford LM, Tone K. Data Envelopment Analysis: A comprehensive text with Models, Applications, References and DEA-Solver Software. Second Edi. Springer Science + Business Media, LLC. 2007. 512 p.
[25] Mukherjee C, White H, Wuyts M. Econometrics and data analysis for developing countries. Paul Mosle. London & New York: Routledge, London & New York; 1998. 515 p.
[26] Fuss M, McFadden DL. Production Economics: A Dual Approach to Theory and Applications, M. Fuss and D. McFadden, 1978, North-

Holland [Internet]. North-Holland; 1978 [cited 2020 Feb 18]. Available from: https://eml.berkeley.edu/~mcfadden/prodecon1.html
[27] Rapsomanikis G. The economic lives of smallholder farmers An analysis based on household data from nine countries. 2015;52(1):114–7. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0080210716307531
[28] Khan H, Saeed I. Measurement of Technical , Allocative and Economic Efficiency of Tomato Farms in Northern Pakistan. International Conference on Management, Economics and Social Sciences. 2011.
[29] Maina FW. Assessing the Economic Efficiency of Milk Production Among Small-scale Dairy Farmers in Mukurweini Sub-county, Nyeri County, Kenya. University of Nairobi; 2018.
[30] Nginyangi JM. Economic Efficiency of Smallholder Coffee Production in Mathira District, Kenya. University of Nairobi; 2011.
[31] Tauer LW. Age and Farm Productivity. 1995;17(1):63–9.
[32] Lema HT. Comparison of economic efficiency of organic and conventional coffee farming systems in Moshi rural district - Tanzania. University of Nairobi; 2013.
[33] Mutoko M c., Ritho CN, Benhim J. Technical and allocative efficiency gains from integrated soil fertility management in the maize farming system of Kenya. J Dev Agric Econ [Internet]. 2015;7(4):143–52. Available from: http://academicjournals.org/journal/JDAE/article-abstract/6EE942E51490
[34] Abdul-kareem MM, Sahinli M. Demographic and socio-economic characteristics of cassava farmers influencing output levels in the Savannah Zone of Northern Ghana. African J Agric Res. 2018;13(4):189–95.
[35] Adeyemo R, Oke JTO, Akinola AA. Economic Efficiency of Small Scale Farmers in Ogun State , Nigeria. Tropicultura. 2010;28(2):84–8.
[36] Ogunleye AS, Adeyemo R, Binuiomote. ASBSO. Cassava production and technical efficiency in ayedaade local government area of osun state , Nigeria. Elixir Agric. 2014;71:24465–8.
[37] Muzungu PG. Technical Efficiency of Smallholder Irish Potato Production in Nyabihu District, Rwanda (Master Thesis, University of Nairobi) [Internet]. 2011 [cited 2019 Feb 23]. Available from: https://ageconsearch.umn.edu/record/243460/