DETERMINANTS OF THE ECONOMIC EFFICIENCY OF CASSAVA PRODUCTION IN BOMI AND NIMBA COUNTIES, LIBERIA

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This thesis is my original work that has not been presented for award of a degree in any other University.

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DEDICATION

This Master Thesis is dedicated to all …

Children, especially the ones vulnerable to malnutrition and food insecurity;

Young people, especially the physically challenged and those in indecent works;

Small-scale farmers, especially food producers with low production efficiency;

and to my Father

Mr. DANIEL B. DOGBA, Sr. (Deceased)

And all departed young and energetic folks; especially…

Ernest Chukuboy Knightley (The Salvation Army-Liberia)

Teolo Seoking (Agape, Cathedral of Hope-Liberia)

James Passawe (IPTP Batch-4)

Little Alice Belleyema (Family, Liberia)

William G. Jallah (Orange-Liberia)

and Mary M. Konneh (Smythe Road)

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Third, I would like to acknowledge the African Economic Research Consortium (AERC) for funding my study. Also, I also want to acknowledge the AERC/CMAAE program team for the support which enable me to travel back home, and participate in the funeral rites of my father, thank you!!! Also, I want to acknowledge all stakeholders and sponsors of AERC, especially the African Development Bank Group, for the grants which catered to my study.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

AfDB	Africa Development Bank
CAR	County Agriculture Representative
CBL	Central Bank of Liberia
CFSNS	Comprehensive Food Security and Nutrition Survey
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Statistical Database
GoL	Government of Liberia
HLPE	High-Level Panel of Experts on Food Security and Nutrition
IFAD	International Fund for Agricultural Development
LNCSS	Liberia National Cassava Sector Strategy
MoA	Ministry of Agriculture
MoA-RL	Ministry of Agriculture, Republic of Liberia
MoCI	Ministry of Commerce and Industry (RL)
NCCC	National Cassava Coordination Committee
NGO	Non-Governmental Organization
SDGs	Sustainable Development Goals of the United Nations
SSA	Sub-Sahara Africa
WFP	World Food Programme

ABSTRACT

Cassava is both a food and a cash crop. It is the only crop of the root and tubers group that is cultivated in all tropical regions of Latin America, Africa and Asia. More than 450 million Africans consume cassava daily as a staple. In Liberia, more than 74% of the agricultural households in Liberia cultivate cassava. Yet, there is still low domestic food production. The mean supply of cassava output is short of the regional average of 10 metric tonnes per hectare. And, there are knowledge gaps and dearth of empirical studies to inform stakeholders about the efficiency of cassava production. Hence, the study sought to analyze determinants of the economic efficiency of cassava production in Bomi and Nimba counties.

Using a multistage sampling technique, primary data was collected from 303 farmers. Data was analyzed using STATA 14.2 and Microsoft spreadsheets. Two stochastic frontier models, using Trans-log production and revenue functions, were estimated to determine the economic efficiency of cassava production in Bomi and Nimba counties; and a two-step stochastic meta-production frontier was estimated to compare the technical efficiency of production resources in the subsector.

From the stochastic frontier models, the mean technical, allocative and revenue efficiency scores for Bomi farmers were 63.4%, 57.4%, and 40.6%; and for Nimba farmers were 31.7%, 31.1%, and 13.5% respectively. The key determinants of revenue efficiency in both regions were the farmer's age (with a negative effect) and farming experience (with a positive effect). The mean meta-frontier technical efficiency (MTE) was determined at 40.48 percent. Gender (1=female) and access to credits were the determinants of the metafrontier. The study recommends more involvement of women and young farmers through farmer field schools. Also, a multi-stakeholder venture offering microfinance services including, microcredits and farming insurance is needed to improve the production efficiency of cassava farmers.

CHAPTER ONE

INTRODUCTION

1.1 Background

Cassava (Manihot Esculenta) is the only crop, from the roots and tubers crop group, cultivated in all tropical regions in the world, including all the sub-tropical countries in Asia. It is the fifth most important staple crop after maize, rice, wheat, and potatoes, and the second most vital African staple consumed per calorie, after maize. On average, two out of every five persons in Africa consume cassava, with more than thousand calories of cassava required in diets by people in the Democratic Republic of Congo (DRC) and Tanzania. Globally, the motives for cultivating cassava vary per region. In sub-Sahara Africa, countries cultivate cassava mainly as a staple. In Asia especially in Thailand, India, and China, cassava is cultivated and traded mostly for industrial purposes, while cassava is cultivated in Latin American countries, especially Brazil and Columbia for consumption and industrial purposes (Lah *et al.*, 2018; Lebot, 2009; Nweke *et al.*, 2002).

Cassava is a famine resilient crop that is regarded as one of the food crops expected to support global food security and increased income especially for smallholder farmers in sub-Sahara Africa. Compared to other root and tuber crops, the demand for cassava is estimated to provide food and income to more than two billion people in Africa, Asia, and Latin America by 2050 (Scott *et al.* 2000).

The rise in production of cassava has been largely attributed to increasing farm sizes, cassava's biological attributes of tolerance to drought and pests, and its viability to varying environmental conditions. Nigeria, which has been the consistent highest cassava producing country, is currently ranked the world's largest producer of cassava, followed by Thailand, which is also the largest exporter of cassava products. By the 2018 ranking of top-producing countries (see Table

1.1), DRC, Ghana, Angola and Mozambique joined Nigeria as the other African countries among the top ten cassava producing countries (FAOSTAT, 2020a).

Table 1.1: A Ten-year comparison of output and land use by the Top Cassava Producers

	2006			2018		
Rank	Country	Production (Tonnes)	Areas Harvested (Hectare)	Country	Production (Tonnes)	Areas Harvested (Hectare)
1st	Nigeria	45,721,000	3,810,000	Nigeria	59,475,202	6,852,857
2nd	Brazil	26,639,012	1,896,509	Thailand	31,678,017	1,385,817
3rd	Thailand	22,584,402	1,070,806	DR Congo	29,952,479	3,677,998
4th	Indonesia	19,986,640	1,228,459	Ghana	20,845,960	1,032,990
5th	DR Congo	14,989,440	1,877,355	Brazil	17,644,733	1,205,413
6th	Ghana	9,638,000	790,000	Indonesia	16,119,020	697,384
7th	Angola	9,037,023	771,072	Viet Nam	9,847,074	513,021
8th	India	7,854,900	244,600	Angola	8,659,552	779,682
9th	Viet Nam	7,782,500	475,200	Mozambique	8,525,451	1,058,023
10th	Tanzania	6,158,300	993,171	Cambodia	7,646,022	272,172
	Africa	119,507,229	12,393,701	Africa	169,673,737	18,681,232
	World	223,636,615	18,884,111	World	277,808,759	24,590,818
	Change from 2016 to 2018	Production (Tonnes)	Areas Harvested (Hectare)			
	Africa (Total)	42%	51%			
	World (Total)	24%	30%			

Source: FAOSTAT, (2020a)

This shows that expanding farm size alone is not sufficient for increased cassava yield. There has to be other considerations to achieve higher yield level even from small farmlands, as is seen with Cambodia which is in the tenth place for cassava production, but tops when yield levels are calculated. The share of cassava production by continent, shown in Figure 1.1, indicates that African countries cultivate more than half of the global cassava shares (FAOSTAT, 2020b).

Cassava is exported from Africa as a staple, for animal feeds and industrial purposes (FAO/IFAD, 2004).

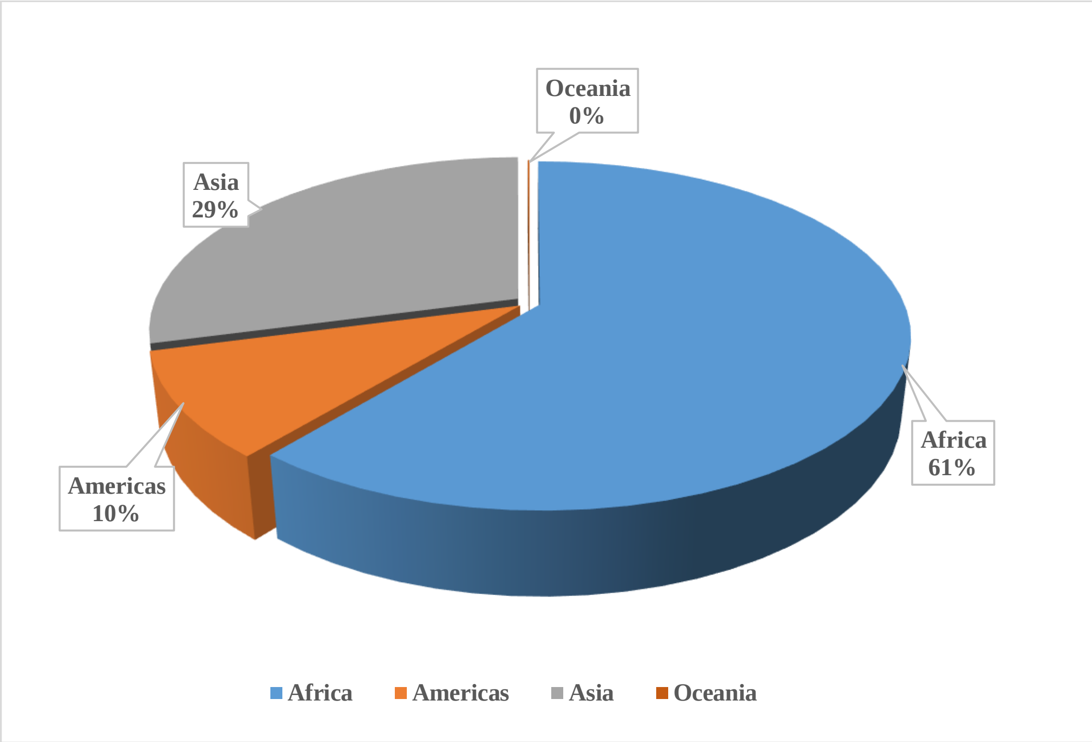

Figure 1.1: Global Share of Cassava production by Region 2006 - 2018
Source: FAOSTAT, (2020b)

The trend of the top global cassava exporting countries, presented in Figure 1.2, shows that Thailand export's share is more than sixty-five percent (65.54%) of the global cassava export, and China is the largest importer. Tanzania and Uganda are the only African countries amongst the top ten cassava-exporting countries (FAOSTAT, 2020c).

Major destinations of cassava exports are North America and Europe with enormous markets for cassava products developing in emerging in Asia. This demand for cassava by Asian markets for industrial purposes provides a suitable opportunity for African countries to export. (FAO/IFAD, 2004; Lebot, 2009).

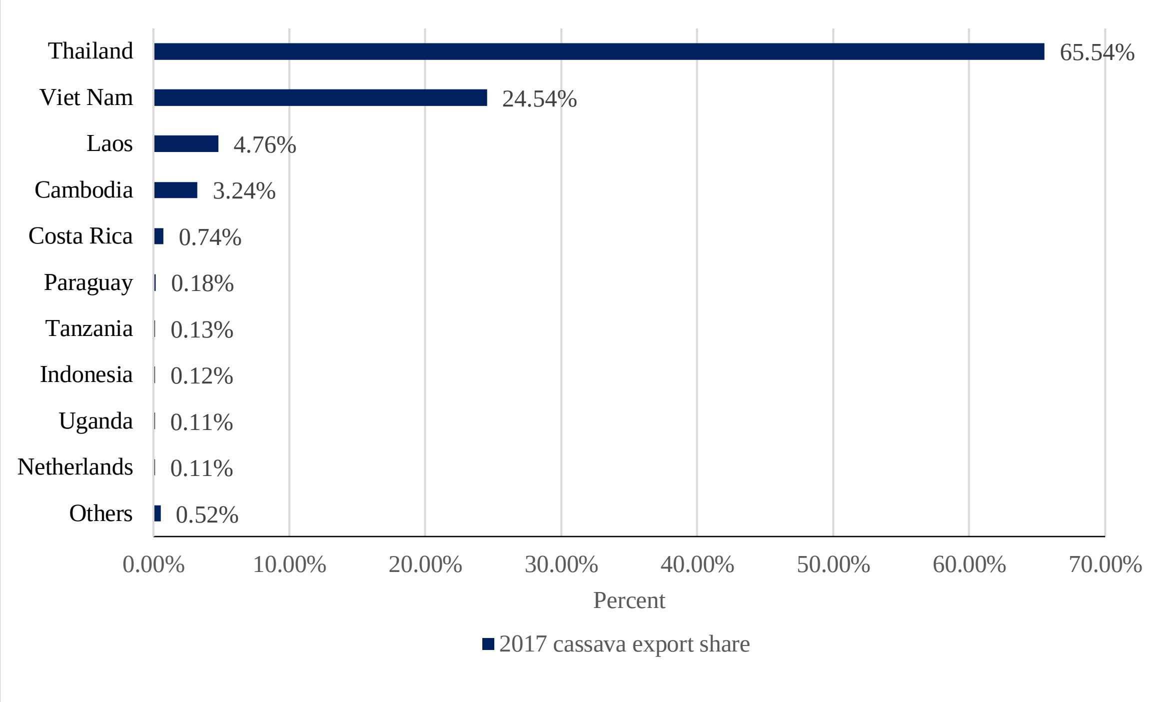

Figure 1.2: Global Share of The Top Ten Cassava For Exporting Countries - 2017
Source: FAOSTAT, (2020c)

To analyze cassava production in Liberia, the reasonable entry point is to meet farmers on their cassava farms, particularly the smallholder farms within the country. The mean cassava farm size across the country is postulated to be no bigger than a hectare, with the MoA agricultural assessment setting mean cassava farm size at 0.51 hectare, and mean rice farm at 1.18 hectares. Most farmers' motives for cassava production are mainly to meet feeding needs.(MoA-RL, 2009; 2010; 2012).

The Government of Liberia's support to the cassava sub-sector led to the setting-up of the National Cassava Coordinating Committee (NCCC). The goal of NCCC is to pilot the sub-sector through policies that will pollinate the value chain for economic growth and development. (MoA, 2007a,b,c; WFP/CFSNS, 2009).

Yet, there are still challenge along the sub-value chain. Toward the forward-links analysis of cassava production, cassava is done for household consumption, local processing and for local trading in rural domestic risk-prone markets that are mostly nearby the production areas, where economic markets are missing, and public infrastructure are dominantly damaged. (Coulibaly *et al.*, 2014a; WFP, 2013; MoA-RL, 2009). On the backward-link analysis of cassava production, accessing microcredit, fertilizer, and high yield stems/cuttings are among the production challenges farmers faced. Stems and labor types (of family, hired and labor reciprocity) are the fundamental inputs used for cassava production in Liberia. The absence of extension services, especially "the on-time information", and high wages to hire labor are the major constraints. (MOA, 2007b).

Economic efficiency requires farmers to use resources in ways to gain the highest possible output given available inputs, using the lowest cost (or attaining the maximum revenue) from resource combinations based on relative input (or output) prices, and an interactive assumption of the farmer to either minimize cost, maximize revenue or profit (Coelli *et al.*, 2005; Kumbhakar & Lovell, 2000). Better farm economic efficiency is expected to improve livelihood by making food available, opening markets for higher farm income and activating trade among value chain actors (input traders, processors, distributors, and local financial institutions) toward growth of an economy and a sustainable development (MoA, 2007).

1.2 Statement of the Research Problem

Cassava is one of the most important food crops in Liberia. Its output has always been higher than other food crops. However, before 2003, agriculture's GDP did not explicitly indicate the contribution of the crops. Cassava was assumed to contribute lower to agriculture GDP due to its relative abandonment: the crop was considered solely for rural consumption (Ravindran, S. & Kenkpen, 1992). In 2003, the GOL challenged with the post-war recovery of the economy and high import cost of domestic staple did an agricultural assessment of the agricultural sector. From the assessment reports, the GoL picked cassava as the choice-crop to supplement rice, assured food security, and reduced poverty through value addition and exports (MOA, 2007a; MOA, 2009). The dearth of technical information about the cassava sub-sector led to a call for research to strengthen policies and interventions that will boom the cassava value chain, create jobs and improve the livelihood of value chain actors

A regional study of the cassava value chains in Cote d'Ivoire, Ghana, Nigeria, Sierra Leone, and Liberia revealed that the cassava production level in Liberia was still short of meeting domestic demand. The average cassava yield in Liberia stands between 6-7 metric tonnes per hectare, which is lower than the regional mean yield of 10 metric tonnes per hectare (Coulibaly *et al.*, 2014b; LISGIS-RL, 2017). Even with the continual rise in the national cassava output, there is no clear empirical explanation to validate cassava farmers' level of technical efficiency nor ascertained their economic efficiency. Farmers may be underutilizing inputs or using high-cost inputs (or technology) to produce higher output. And, with higher production costs, farmers could be incurring losses, making lower profits, and undergoing poorer livelihood due to economic inefficiency. Hence, there is a need to clarify these doubts by analyzing the economic efficiency within the cassava sub-sector.

The GoL has an export agreement with China which offers duty-free imports on 99% of Liberian agricultural goods, scraps and natural resources (MoCI, 2017). Because China is the largest importer of cassava outputs and products, there is an opportunity for cassava farmers to increase cassava production and export for higher revenue using this agreement (FAOSTAT, 2020a). In order to export cassava to China using this export agreement, there is a need to develop an export strategy which will primarily rely on the production level and efficiency of cassava farmers to sustain or increase the export level. Hence to inform stakeholders, there is a need to assess cassava production schemes and technologies used within the counties, and the determinants of economic efficiency in the cassava sub-sector.

1.3 Objective of the Study

The research objective of the study was to analyze the economic efficiency of cassava production in Bomi and Nimba Counties, Liberia. Specifically, the study sought:

a) To characterize cassava farming in Bomi and Nimba counties

b) To determine the economic efficiency of cassava production in Bomi and Nimba counties

c) To determine the Meta-technical Efficiency (MTE) of Cassava production in Bomi and Nimba counties

1.4 Hypotheses

The study tested the null hypotheses of the second and third specific objectives as follow, that:

b) Smallholder cassava farmers in Bomi and Nimba *are not* economically efficient;

c) Cassava farms in Bomi and Nimba counties *are not* fully utilizing the capacity of available inputs in the cassava sub-sector.

1.5 Justification of the Study

The research study is justified for the following reasons:

First, knowledge of farm-level efficiency will provide important information to farm managers in planning, budgeting and allocating resources (or resource services) among enterprises. It will assist managers to determine the required input adjustments leading to increased production, improved production methods, and enterprise diversification (or specialization);

Second, the economic efficiency of smallholder cassava farmers in Liberia aligns with the research and development (R&D) needs of the Government of Liberia. This need is supported in National policy frameworks including the Comprehensive Assessment of the Agriculture Sector, the Rice and Cassava (specific) sector strategies, Food And Nutrition Surveys and the National Poverty Reduction Strategy Agenda (MoA, 2010). The GoL calls for empirical research on cassava for effective policy analysis to optimize the potential, boost the Liberia Agriculture Sector and stimulate economic development (GoL, 2018);

Third, the study evaluates the effectiveness of the economic theory of production, farm efficiency and technology used to the reality of cassava production efficiency in Liberia. Findings contribute to the body of empirical efficiency and metafrontier literature, and the application of efficiency and metafrontier measurements with real agricultural cross-sectional data from Liberia. From reviewed literature concerning the Liberia agriculture sector, this research thesis contributes as the first stochastic metafrontier study on cassava production;

Fourth, Cassava farm-level efficiency will unveil business opportunities by providing information for agribusiness intervention in the cassava sector. By determining the economic efficiency of cassava farmers, the supply chain will support employment, increase rural farmers' income and foster agriculture-led economic development through agribusinesses.

1.6 Organization of the Thesis

This thesis is structured into five chapters. The first chapter has the introduction, statement of the research problem, objectives of the study, hypotheses, and justification of the study. The second chapter provides reviews of the related literature. The third chapter has the conceptual, theoretical and empirical frameworks, description of the study area, sampling procedure, data collection, data management and analysis, and diagnostic tests. The fourth chapter provides the results of the study, and the fifth chapter has the summary, conclusion, recommendations and areas for further research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Cassava Production

2.1.1 Cassava Production and Perspective in Africa

Africa alone produces more cassava than the rest of the world. The production trends for six major African staples (see Figure 2.1), and their land utilization per hectares harvested (see Figure 2.2) revealed that cassava is a lower land-utilizing crop with greater efficiency, and higher productivity than maize, sorghum and millet (FAOSTAT, 2020d). The total cassava production in Africa increased by forty-two percent from 119.5 million metrics tons in 2006 to 169.67 million metrics tones in 2018. The increase was harvested from a fifty-one percent expansion of cassava farmland from the 2006 total land area of 12.4 million hectares (Spencer & Ezedinma, 2017; Lebot, 2009; Nweke *et al.*, 2002).

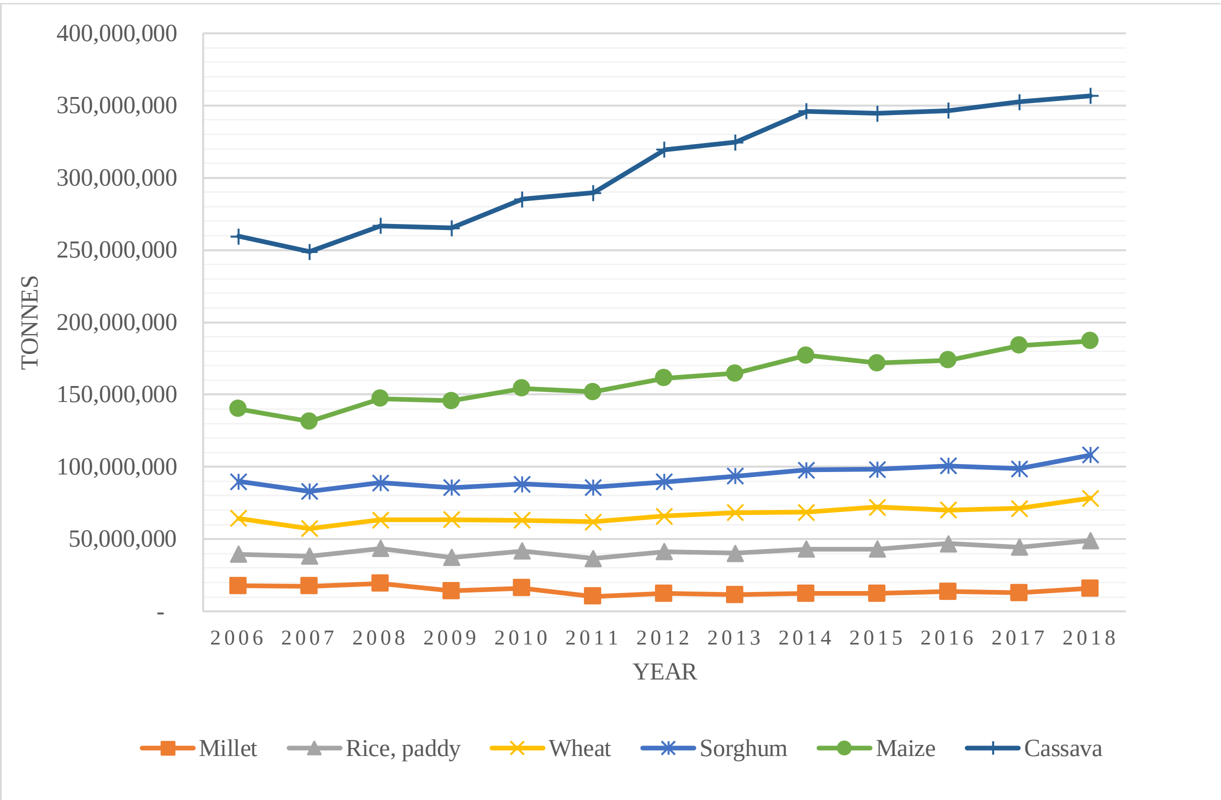

Figure 2.1: Production trends of Six (6) major African Staples, 2006-2018

Source: FAO STAT, (2020d)

More than seventy-five (75) percent of SSA countries cultivate Cassava primarily for consumption, making it a significant crop to the livelihood of more than ninety percent farmers that are cultivating on-farm plots of two hectares or less (Rapsomanikis, 2015; Spencer & Ezedinma, 2017).

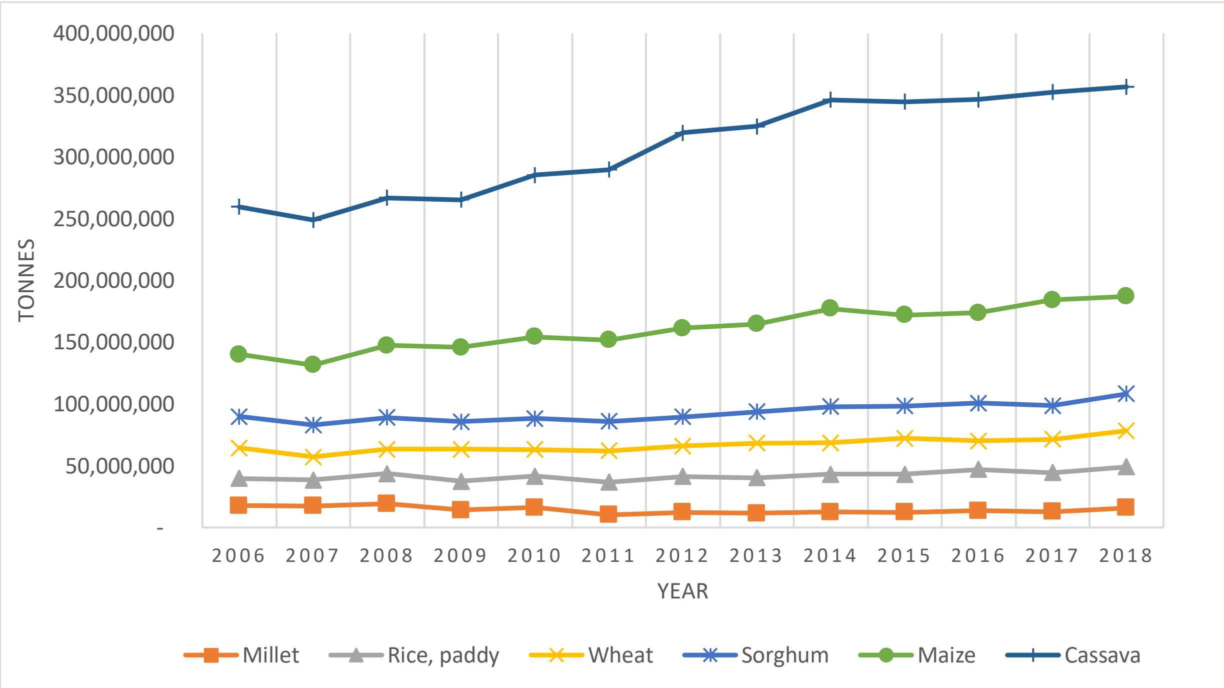

Figure 2.2: Trend of Harvested Areas for Six (6) major African Staples, 2006-2018
Source: FAO STAT, (2020d)

Cassava had been used in Africa, in the history of food security and livelihood sustainability to sustained rural food security during drought and famine, compensated for low-cost animal feed, influenced urban consumption through value-added consumables, and became an income-generating cash crop that supported industrial raw material (Lebot, 2009; Nweke *et al.*, 2002). Africans consume ninety-three percent (93%) of the cassava they produced as a staple, used six percent (6%) for animal feed, with less than one percent (<1%) for industrial use and post-harvest spoils (Nweke *et al.*, 2002). Farmers in Tanzania, Nigeria, Cote d'Ivoire, Uganda, and Kenya are incorporating cassava into the animal dietary requirements to increase the use of cassava (Hahn, Reynolds, & Egbunike, 1988; Nweke *et al.*, 2002).

The “untapped” potentials of cassava to serve as a cash crop, access urban markets as staples and to serve as industrial raw materials for income generation, improvement of rural livelihood and boosting economic growth in African countries is referred to as "Africa best-kept secret” (Nweke *et al.*, 2002). This secret stands at the core of robust agriculture transformation for many African countries; something that should be encouraged if countries intend to launch “impacting agriculture-leading” growth for sustainable economic development (Diao *et al.*, 2010).

In a collaborative study of cassava in Africa (COCSA) covering six African countries in three regions, cassava is expressly pronounced effective for land-use intensity. Crops affected by Cassava land-use intensity are mostly food crops in humid and non-humid zones. Unique from other continents, many African countries considered cassava as either a primary or a secondary staple . Nigeria and Ghana, in West Africa, are the largest cultivators of cassava; harvesting cassava yields above the regional mean yield of 10 tonnes per hectares (Spencer & Ezedinma, 2017; Nweke *et al.*, 2002; Okigbo, 1980).

Farm-level research to improve efficiency, scale-up productivity and technical change has been ongoing for a long time to increase yields, meet consumer demand, animal feed and improve livelihood (Hahn, Reynolds, Egbunike, 1988). Focused research mandates on roots and tubers like cassava, potatoes, sweet potatoes, taro yam, and groundnuts, and some cereals like maize, millet, sorghum, and rice are assigned to the International Institute of Tropical Agriculture (IITA): a consortium member of Consultative Group for International Agriculture Research (FAO, 1996). The IITA headquarters sits in Nigeria, West Africa. This increased the possibility for farmers in the region to benefit from research innovation, adopt high-yielding varieties and exposures to contemporary extension and scientific yield-boosting knowledge about cassava production (Nweke *et al.*, 2002).

2.1.2 Cassava Production, Food Situation, and Agriculture Exports in Liberia

Agriculture GDP accounts for 25.8% (CBL, 2017) with seventy percent of the active labor force employed in the agriculture sector. The agriculture sector is the main source of livelihood for many Liberians; because, more than two million people with many residing in rural areas directly earn their livelihood from farms or farm-related activities (MoA-RL, 2009; MoA, 2010, 2012). Cassava is one of the most important food crops in production and consumption (WFP, 2013). It is the second most food crop mostly cultivated by many farm households, rice been the first food crop. From allocated food production areas, 57,360 hectares representing 20.5% are used to cultivate cassava. The fresh cassava tubers cultivated on these land account for 64% of local cassava staple produced (MoA-RL, 2009).

As a land-use effective food crop, cassava is cultivated on twenty percent of the 280,030 hectares used to produce food in Liberia, seventy-nine percent cultivated by rice, and the remaining by vegetables. Despite the level of land allocation between food crops, Cassava production doubles rice production for all the compared periods (see Figure 2.3). This signal an important prospect to consider for food security and other purposes including employment and higher farm income (FAOSTAT, 2020e; MoA, 2009).

Despite the abundant production of cassava over rice which is the primary staple, there is still a low supply of cassava to supplement food crops and help meet the local demand (Coulibaly *et al.*, 2014a). The shortage of domestic food demand leads to high imports of food crops. High imports contribute to macroeconomic disturbances like capital flight, inflation, depreciation and lower investment incentives which impact the exchange rate and nominal price of goods and services This has become a pertinent driver among the factors leading to increased poverty and challenging livelihood in rural areas, especially among the smallholder farmers (CBL, 2017; Tsimpo & Wodon, 2008).

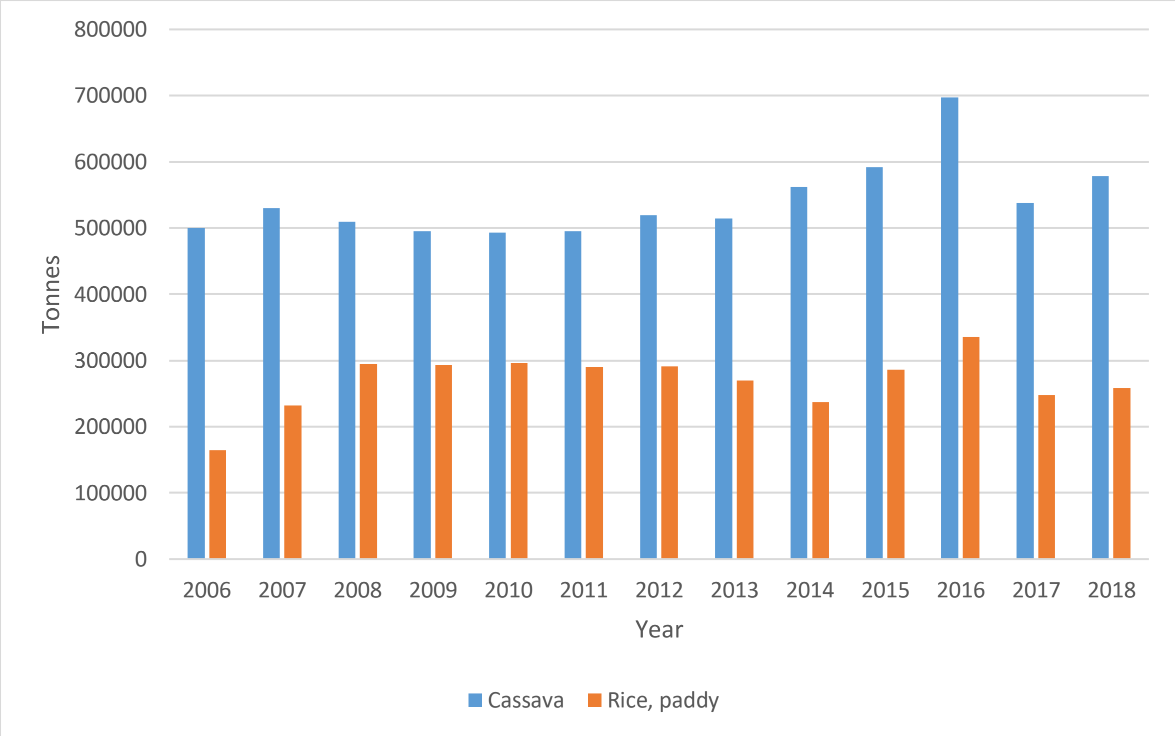

Figure 2.3: Comparison of cassava and rice production in Liberia for 2006-2018
Source: FAOSTAT, (2020e)

Food insecurity is common in many parts of the rural areas. The distribution of decent livelihood incentives is skewed toward urban and peri-urban areas. Residents farther from urban settlements faced higher vulnerability to food insecurity through higher proportionate food expenses from their income (WFP, 2015).

Liberia's leading cash crops are rubber, cocoa, coffee, and palm oil. Using intercropped farm practices, more than two-third of the active labor force cultivates either food crops for sustenance or cash crops for farm income, while the remaining active labor force is shared among secondary and tertiary sectors. Vegetables are mostly cultivated to generate farm income in domestic markets closer to production areas. A livelihood support system, through reciprocity, where farmers share farm inputs and planting materials is popular among farming households (WFP, 2013; MoA, 2009). Cassava and local rice produced are mostly sold in local rural markets with some locally manufactured cassava products like gari, and fufu (Coulibaly *et al.*, 2014a). Farmer's exchange different goods and services at unvalued market prices by sharing and redistributing inputs and outputs mostly for the general survival of the community. In Liberia, five percent of all cultivated food crops are shared as gifts especially among members of a farming cooperative, and two percent is used as re-payment for inputs, loans or output borrowed in previous agriculture season (WFP, 2015; MoA, 2009; Ellis, 1988).

2.2 Empirical Review

2.3.1 Empirical reviews of related literature on Productivity and Efficiency

In a study analyzing public and private extension service delivery to cassava farmers in sanniquellie and saclepea mahn districts in Nimba county-Liberia by Lah *et al.*, (2018), the researchers using multiple regression estimates and factor analyses found that there was a significant difference in the provision of public and private extension services. While farmers had low adoption of public extension services, there was far lower adoption of private extension services implying that adoption of extension services among cassava farmers is low in Liberia, and there are higher challenges of private extension businesses compare to public extension service. The study, however, failed to assess the inefficiency effects and the relationship of extension services to efficiency for higher productivity.

The low adoption of extension services can be traced to low access and unavailable credit to farmers. Roberts *et al.*, (2017), in analyzing credit access and use to smallholder farmers in Bong-Liberia, found from the binary logit regression analysis that most of the farm household heads were male farmers regardless of the level of access to agriculture credits. Their findings also connote that farmers with a higher level of education were more likely to access credits because they were more likely to participate in other non-farm activity, and more likely to generate non-farm income. Been significant for the estimation, formal education contributed to the awareness of better production methods, increased the chances of a farmer to receive credit from a formal financial institution, and increased adherence rate to the application of the credits for the intended agriculture purpose. Yet, the study ignores the role of men and women within farm activities, and how higher revenue contributes to the economic efficiency of farmers. This study extends the assessment of farm revenue to the economic efficiency of cassava farmers.

Production is also affected by institutional issues. Colonial affinity and association also influence the level of political and economic institutions. Studying aggregate productivity to gain a comprehensive understanding of Agriculture productivity growth in Africa based on colonial heritage and institutional factors, Fulginiti, Perrin, and Yu (2004), found that the arrangement of heritage institutional factors (or former colonial master), civil liberties and politics were major factors to a country's productivity. The result showed that Liberia had low agriculture productivity due to the prolonged civil war and based on harsh politics. The foundation of credible institutions upon which agricultural policy should be laid is significant to a country's agriculture growth. While this study focused on aggregate data using factor analyses, it missed out on the specificity of the institution's effects in the subdivisions. The current study used disaggregated data to assess farmer's economic efficiency of farmers in sub-divisions while assessing institutional variables as determinants in each of the subdivisions.

In the bid to promote agriculture growth, the effectiveness of markets is important for farmers to seek increase income from their production. Handwerker (1981) measured productivity, marketing efficiency and price support programs as alternatives to the improvement of rural livelihood in Liberia, and established that on-farm yield (output per hectare) was the best indicator to measure national productivity. The flow of supply to markets was not enough to explain national productivity. Firm-specific analyses rather than macro-economic attributes were better in measuring efficiency for rural improvement. From factor analyses, it was found that age, gender, farmland, fertilizer inputs, and corporative labor were positive and significant to productivity. A critique of this study is that it followed the flow of market supply to determine national productivity. This way, national productivity will be understated because farmers also have a sustenance motive for producing food crops, it left out two key factors of productivity: "access to credit" and "extension contact". To this, the current study collected primary data from farmers and assess the farmland, extensions and access to credits as part of the determinant of economic efficiency.

In a two-step qualitative desk study of theoretical data analysis on the Cassava Value Chain in West Africa, Coulibaly, *et al.,* (2014) studied five African countries (Cote d'Ivoire, Sierra Leone, Ghana, Nigeria, and Liberia) and found that consistent among smallholder farmers was a common challenge of access to and uptake of extension services at the appropriate time. The study also found that Cote d'Ivoire, Ghana, and Nigeria were meeting their local demand for cassava from the local production of cassava. In Liberia, the study found that producers popularly used improved local varieties; even though a study four years later showed that farmers use unimproved local cassava varieties in Saniquellie mah district, Nimba (Lah *et al.,*2018).

To estimate the level of economic efficiency of smallholder sweet potatoes producers, and analyze efficiency determinants in Delta, Nigeria, Gbigbi (2011) found that all production factors for potatoes were positive and significant. Using the Cobb-Douglas functional form of the stochastic frontier models (of production and cost), and the Tobit regression to analyze the determinant of efficiency. From the findings, the level of formal education, years of farming experience, access to extension services, and access to credit significant were positive efficiency determinants while cooperative membership was negative and significant to economic efficiency. There is an inherent limitation to two-step of the stochastic frontier models; because, the inefficiency is assumed to be independent in one of the models. The current study will assess these and other determinants in a one-step estimation using production and revenue (rather than cost) functions to estimate the revenue efficiency.

To analyze the technical and allocative efficiency of sweet potatoes and measure production efficiency in Imo, the authors Nwaru, Okoye, & Ndukwu (2011) using stochastic cost function analysis found that age and formal level of education were insignificant at all level of significance. Insignificant variables were capital and price for planting material. Also using similar cost function to estimate the allocative efficiency, Ogundari & Ojo (2006), researched how the efficiencies affect cassava production for food and exports in Osun state, Nigeria. The study found the age of the farmer as the only significant determinant. Though there were high-efficiency scores, age has negative effects on the efficiencies. The current study will venture into the output-orientation using relative output prices to determine the allocative efficiency from the revenue function.

Amaza *et al.*, (2010) estimated farm-level efficiency and national productivity to identify determinants of six seeds production: maize, cowpea, soybean, rice, groundnut, and sorghum in Boro state, Nigeria. Using cross-sectional, primary data from 396 respondents, the Cobb-Douglas stochastic production frontier, gross margin, and the maximum likelihood procedure were used. The authors found that quality seeds were crucial for agricultural productivity and recommended that policy continues support to seed producers. While the focus of this study was on seed-producing plants, it covered most of the major African staples but left out cassava. Hence, this study sought to determine the farm level efficiency for cassava production.

Adeyemo, Oke, & Akinola (2010) investigated the profit and efficiency of cassava production in Ogun state. Using data from 200 farmers, the stochastic frontier models, and maximum likelihood estimation, the authors found the popular source of land acquisition to be “by land inheritance”. The source for the cassava planting material mostly from old farms. The quantity of planting material and farm size were significant to output, while age and farming experience contributed to technical efficiency and productivity of cassava in Ogun state. Land acquisition is important in explaining the contribution of institutions to economic efficiency through the nature of assigned property rights and collective actions over the land and its resources. This institutional connection of land acquisitions for the cassava farm was assessed in the current study through the variable “land source”. This variable “land source” was also assessed in the context of understanding the motivations underlying access to land.

Results from a study on profit efficiency among cassava farmers by Oladeebo & Oluwaranti (2012) found that the most important positive farm variable for profit efficiency is the price of agrochemicals (significant at 5%). The negatively significant variables that influence profit are household size, and farm size (significant at 5%). To increase income, farmers are encouraged to increase farm size, adopt high yielding technology relying on the biological attributes that cassava does survive in many environments.

While a farmer's preference for the adoption of technology influences the level of anticipated production, the location of farmland and the motivation of a farmer to produce either on a small scale or on a larger scale has important ramifications. Howeler *et al.,* (2012) studied the challenges of large scale cassava production and found that large scale cassava production is usually done in remote areas where they faced challenges of the remoteness of unoccupied land, lack of labor (and specialized skills), machinery and planting materials. Such a challenge increases the cost in large scale production of cassava. Remote land is unattractive and lack the public infrastructure to markets, or sustain regular cassava planting and harvesting all year round. Hence, the location of the farm was assessed in the current study to verify if remote farms had more challenges, compare to urban and peri-urban associated farms; and if there is a trend in the technical and allocative efficiencies based on the location of the farm.

2.3.2 Empirical reviews of related literature on stochastic metafrontier analysis

Villano *et al.,* (2010) in a study to assess the appropriateness of the metafrontier analysis, set two necessary conditions using the second stage deterministic metafrontier model. The first condition was to assess if all farmers have access to the same technology but were not necessarily using the available resource at the same level, and the second was to assess using statistical test if farmers could be gauged on a similar production function if they cannot readily adjust to optimal production set. The Translog Pistachio production and a panel data of three districts over two years were used. The result confirmed that TGR provides a valid score for correcting technical efficiency scores predicted from joint data. The conclusion was explicit; that it is misleading to compare the performance of different pistachio trees based on the output or yield alone. Rather, consideration of the two conditions is a necessary condition and a reliance to use the metafrontier for regional analysis.

On the motivation of maintaining food security and nutrition for the growing population, and to provide pieces of evidence for use the meta-frontier analysis on agricultural productivity using county-level data, Chen & Song, (2008) studied the efficiency and TGR in China agriculture using regional demarcations of east, northeast, west and central China. From the production estimates, the TGR varied between 0.62 and 1. Using the Tobit model to explain significant determinants, population density showed non-linear with the TE, TGR and MTE indices; non-agricultural GDP was negatively related to TGR but positive with MTE; and Credit availability had a positive relationship with TGR but negative correlation with TE and MTE.

In another study on the technology gap and china's regional energy efficiency using parametric Metafrontier approach, Lin and Du,(2013) intending to provide new evidence on energy performance using regions (east, central and west) to analyze the efficiency of energy for sustainable development. Using the Translog shepherd energy distance function and the sum of squared deviation in the second stage deterministic metafrontier analysis, the value of the TGR ranged from 0.3237 to 1. They focused only on the indices and ignored determinants, they found the mean TGR for east, central and west regions at 0.9504, 0.7884 and 0.4012 respectively. These indices indicated greater efficiency of energy use in these regions when compared to other regions.

In an investigation to validate if firms with foreign capital are more efficient than their domestic counterparts in the Turkish manufacturing industry, Tunca, *et al.*, (2013) used the second stage deterministic meta-frontier framework to analyze panel data from 1992 to 2001. The mean TGR ranged from 0.9642 to 1. The firms with foreign associations were found to be more efficient with mean MTE of 0.8975, compared to domestic firms with mean MTE of 0.8198. However, domestic firms were found to be more efficient in the use of the sector's technology, having TRG of 0.9866, than their foreign counterpart with TGR of 0.9781. The indication was that domestic firms were catching up by being efficient in the use of available resources in the manufacturing industry since they had no foreign capital affiliations.

To account for realistic methods in soliciting management and policy intervention and advice about the efficiency of the Norwegian dairy farms, Alem, *et al.*,(2017) used the two-stage stochastic metafrontier framework to analyze five regions (East, South, West, Central, and North). Using the Translog production function, the mean indices for the five regions were in the ranges of 0.89 to 091 for the technical efficiencies; 0.96 to 0.98 for the technology gap ratios, and 0.87 to 0.89 for the meta-technical efficiencies. Using the variables of farmer experience, government subsidy, the number of cows, debt and asset ratio were used to analyze group TEs and TGRs, and the regional grant index and off-farm contacts to explain the determinants of MTEs, the study found that subsidy and the number of cows were significant at 1% in all regions, even though they had contrasting effects on the efficiency of dairy farms. Subsidy reduced the efficiency of farmers and the number of cows increases the efficiency of dairy farms. For the debt/asset ratio, all regions were affected by a decreasing effect of the variable on technical efficiency. Farming experience increased efficiency in all regions besides western Norway. Grant index reduced the regional meta-frontier efficiency, and non-farm contacts had increasing effects on the meta-technical efficiency.

With the objective to re-estimate and analyze the wheat farmers using a flexible function, a larger data and consideration to the heterogeneity of production frontier across Kerman province, Boshrabadi, *et al.*, (2006) apply the second step deterministic meta-frontier estimation to a sample of 676 farmers from five regions (south-western, south-eastern, north-eastern, north-western and western) of Kerman, Iran. Based on the production environment and technology heterogeneity of the frontiers across the regions, the authors found that in-group technical efficiencies (TE) vary among the groups; but the TGR of groups to the metafrontier were substantially different among the regions. The mean statistics for TE from the regions ranged from 60.9 to 77.5 percent. The mean TGR among the region was in the interval of 22.6 to 61 percent. This gap showed that the potential to improve resource use in the industry can be expanded through a capacity of 39%, given the same level of production resources. The attributing factors enlisted were lack of water resource and small-farm sizes affected by the technology change and mechanization.

2.3 Summary

From the reviews, it is clear that there are archives of literature on efficiency and cassava production efficiency. Studies differ on the account of variables used, the specific segment of the value chain captured in the study, and the methods used to determine the efficiencies and productivity of cassava and other crops. Studies focusing on efficiencies and productivity in Liberia have been done on the aggregate level; with farm efficiencies been suggested as the best indicator to measure national productivity. There are still knowledge gaps concerning specific farm-level economic efficiency of many cash and food crops. From the review, it is worth noting that there is also a gap in the application of meta-frontier analyses to efficiency of food and cash crops in Liberia. This study leads with the application of metafrontier analysis on food crops using primary cross-sectional data from the cassava subsector of Liberia.

This study incorporated most of the socioeconomic characteristics covered from the reviews to predict and determine the efficiency indices of cassava farms, and to determine the meta-technical efficiency. The stochastic meta-frontier was used to compare the resource-use competences of cassava farmers in Bomi and Nimba counties.

2.4 Hypothesized determinants and their expected (a priori) Signs

The study hypothesized three sets of variables to influence the economic efficiency of cassava production. The set of variables are: the farm-specific characteristics/factors, institutional/ demographic, and economic factors. Variables and expected signs are presented in Table 2.1:

Table 2.1: Variable and the a priori expectations (signs).

Variables	Definition	Variable Measurement	Expected Sign
Cassava Output	Cassava farm production	Kilogram (Kg)	
Planting materials/stem cuttings		Bundles	+
Land		Hectares (ha)	+
Capital /(Tools)		LR$/ qty (pcs)	+ /-
Male Labor	Quantity of men effort offered	Man-day	
Female Labor	Quantity of women effort offered	Man-day	+
Access to Credit	Dummy Variable: No = 1 or Yes = 0	(LR$)	-
Farm group Membership	Non-member = 1, Membership = 0		-
Extension Contact	Access to Extension: 1 = No, 0 = Yes	#s of visit	-
Age of Farmer		In years	+/ -
Gender	Dummy Variable: 1 = female or male = 0		
Marital Status		Categorical	
Household Size	Count of household members	#s of members	+
Education	Formal Education level acquired	Categorical	+
Farming Experience	Year of acquired cassava farming experience	# of farming years	+
Farm Location in Region	1 = Bomi, 0= Nimba		+ /-

Variables	Definition	Variable Measurement	Expected Sign
Off-farm Income	Amount	LR$	+
Distance to Market	A distance of farm to market	In Kilometers	-
Price of Stem Cuttings	the unit price of stem /bundles	LR$	-
Rent of Land	rent/acre of land	LR$	-
Price of machine/ tools	unit prices of each tool	LR$	-
The wage of Female Labor	female wage/ Man-day	LR$	-
Wage of male Labor	male wage/Man-day	LR$	-
Price of cassava output	Farmer's fair output Price	LR$	+

Source: Author's review from Related Literature

CHAPTER THREE

METHODOLOGY

3.1 Conceptual Framework

The economic efficiency of cassava production is attained through a concept hypothesized into three levels (Figure 3.1). In the conceptual framework, level one has the socio-demographic and institutional factors supporting cassava production. The economic factors are within level two, while level three contains the set of farming inputs needed to cultivate cassava production.

From level one, the distance of farm locations from input markets (that is the proximity of farmers to access inputs) and the geographical region of the cassava farm are hypothesized to influence the unit prices of farm inputs (including stems, tools, and labor). Also, it is hypothesized that farmers obtain the economic ability to acquire farm inputs and best production practices based on their demographics and the degree of institutional support they received. For example, membership in farming groups is postulated to influence access to farm group labor, extension service and access to agriculture credit for group members; and, the size of the household, marital status and gender are important influencers to the access of farmland, and the types of labor to use at each stage of the cassava production. Within level two, farmers are postulated to acquire farm inputs at economic cost based both on inputs' per-unit prices. This capacity to obtain inputs is also supported by the level of influence from socio-economic determinants and institutional supports. To attain efficiency in cassava production and increased farm productivity, farmers are assumed to adequately combine the inputs with contemporary cassava production practices within the production phases of land preparation, planting the cassava cuttings and weeding the farm. At level three, the inputs and the best adopted practices when consciously combined are hypothesized to achieve higher output, increase productivity, and achieve overall economic efficiency of cassava production.

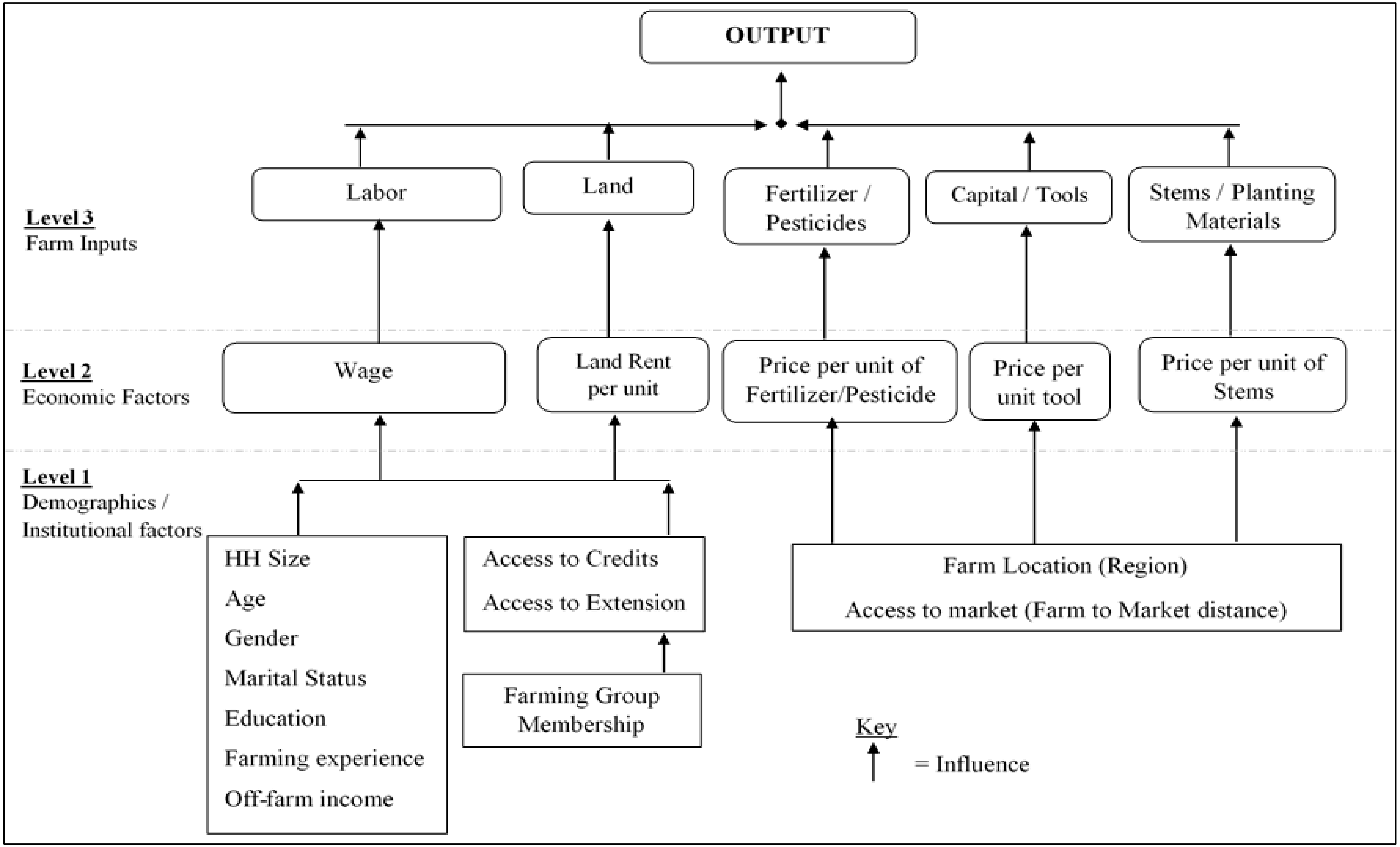

Figure 3.1: Conceptual Framework of Cassava Production in Liberia

3.2 Theoretical Framework

The production theory of the profit-maximizing peasant postulates that the peasant in attaining economic efficiency is aspired by dual goals: first, by attaining profit from the technical-economic aspect of the farm as a business to produce the highest possible output which gives the highest net income measured either in monetary or physical terms; and second, by maximizing profit based on a behavioral content related to livelihood and the household need. This implies that the economic efficiency for a peasant farmer can be computed whether the producer is a subsistence farmer, or a fully commercial farmer (Ellis, 1993). Because it is a critical motive of a farm manager is to gain profit either in a monetary or physical unit, efficiency and profit maximization work together. An inefficient firm experiences lesser optimization of profits (Coelli *et al.,* 2005). Two key methods are used to measure the production efficiency of a firm; namely, the stochastic frontier analysis (SFA), and the data envelopment analysis (DEA). The fundamental differences between the SFA and the DEA lie on whether the researcher intends to use a parametric or non-parametric method (Cooper *et al.,* 2007; Kumbhakar & Lovell, 2000). Based on the behavior assumptions of either cost minimization, revenue maximization, or profit maximization, the SFA and the DEA can utilize an input-oriented or output-oriented procedure to measures the overall efficiency[1]. A fully efficient firm will have an inefficiency score of zero, and vice versa (Ellis, 1993).

The study adopts the Stochastic Frontier Models because it relates to the actual performance of a firm to a standardized performance level of a given technology (Farrell, 1957). By comparing actual output values to a mean production frontier estimated, the technical efficiency effect is predicted; and similar comparison of relative output price and inputs to an optimized revenue frontier is used to predict the allocative efficiency effect. The product of the

[1] It is also known as economic efficiency. Economic efficiency can be a cost, revenue, or a profit efficiency based on the underlying behavior assumptions, prices, and the input/output oriented measure procedure.

technical and allocative effects determines the economic efficiency of cassava production (Aigner *et al*., 1977; Jondrow *et al*., 1982; Kumbhakar & Lovell, 2000).

With stochastic derived models, a metafrontier analysis can be done through one of two frameworks; namely, the second-step deterministic metafrontier model, or the two-step stochastic metafrontier model. The main difference between the two metafrontier frameworks is lain in the used of either a programming methods to solve the solution for the metafrontier with bootstrap or simulated errors (Battese *et al.,* 2004; O'Donnell *et al.,* 2008), or the application of stochastic properties to estimate the metafrontier with robust errors (Huang *et al.,* 2014).

Three features are used to analyze the metafrontier; they are: the technical efficiency of the firm to its group (TE), the technology gap ratio (TGR), and the metafrontier technical efficiency of the firm to the metafrontier (MTE). The TGR is the efficiency level of each group's efficiency to the metafrontier. The relationship of the TE, TGR and the MTE under this stochastic metafrontier framework is presented in Figure 3.2 below:

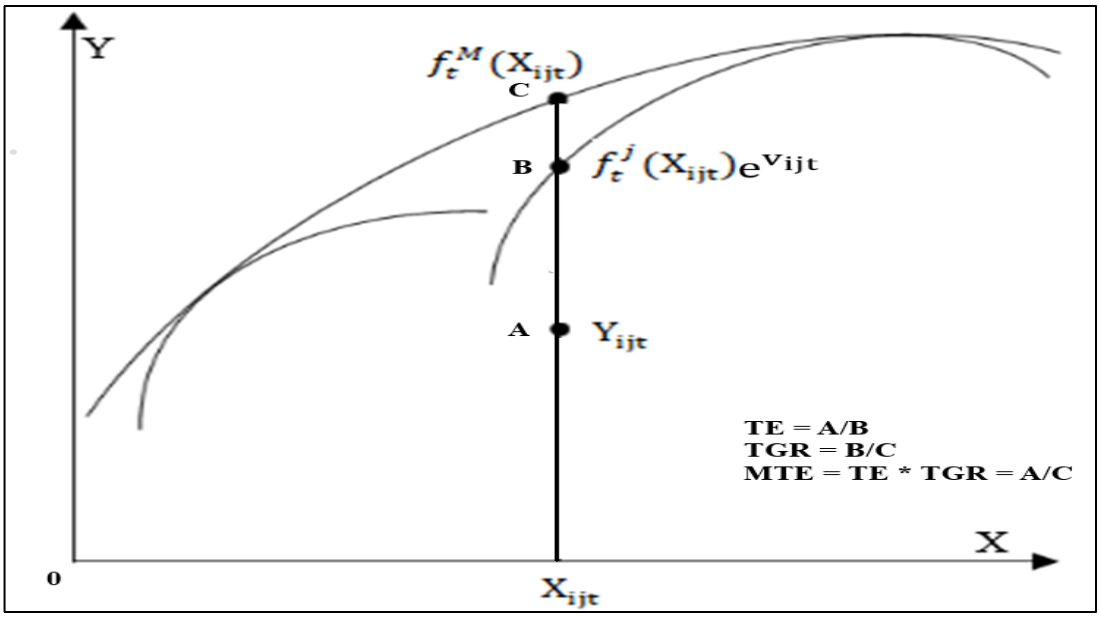

Figure 3.2: Stochastic Metafrontier Production Model
Source: Adapted from Huang *et al*., (2014)

This study adopted the stochastic metafrontier framework to estimate the technology gap ratio (TRG) and determine the meta-technical efficiency (MTE) levels of cassava farmers in Bomi and Nimba counties. This framework is preferred because it induces randomness and inferential characteristics to the estimates, which is viable for policy and decision making.

3.3 Empirical Framework

3.3.1 Specification of the Stochastic Frontier Models

The Translog type of function was used for production and revenue functions. The stochastic frontier production function is presented as follow:

$$Y_i = AX_i^{\beta_i} \ldots X_k^{\beta_k} e^{\left((0.5\beta_{ij})((\ln X_i)^2(\ln X_i)(\ln X_j)(v-u)\right)} \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.1)$$

Y_i = Total observed cassava output of the i^{th} farmer

A = β_0 = parameter accounting for similar technology common to all cassava farmers

$\beta_1 \ldots \beta_k$ = the parameter of each input ($X_1 \ldots X_k$) to be estimated in the production function

β_{ij} = the parameter of the square terms (such as land^2, stem^2) and the symmetry terms[2] (interaction between inputs such as land and stem) to be estimated;

$X_i \ldots X_k$ = production inputs (like stem cuttings, fertilizers, land, tools, labors and so on)

e = exponential growth overtime

v_i = two-side normal error term with mean zero and constant variance

u_i = one-side truncated normal error term of inefficiency from cassava farmer

According to Mukherjee *et al.,* (1998), it is allowable to transform non-linear and curvilinear models to linear models for better data analyses, and easier understanding of complicated models. Therefore, equation 3.1 was transformed using double-log transformation as follow:

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

[2] The symmetry terms follow the identifying condition that $\beta_{ij} = \beta_{ji}$ for all *i and j* parameters

Where, ……..................... (3.2)

ln = natural logarithm

The rest of the other variables remain the same as presented in equation 3.1 above.

Because the production and price functions ascribe to the global approximation of their structural forms, the concept of the revenue frontier is to maximize revenue based on the firm's output level. Therefore, it is possible to represent a convenient revenue function as a vector of inputs and output price in a competitive output market (Christensen *et al.*, 1973; Kumbhakar & Lovell, 2000; Oliveira *et al.*, 2013). Upon these basics, the stochastic frontier revenue function was represented as follows:

$$\ln R_i = \alpha_0 + \sum_{i=1}^{N} \alpha_i \ln(x_i) + 0.5 \sum_{i=1}^{N}\sum_{j=1}^{N} \alpha_{ij} \ln(x_i) \ln(x_j) + \alpha_8 \ln p_y + (v_i - u_i) \quad \text{……. (3.3)}$$

Where:

$\ln(R_i)$= the varied total revenue of a cassava farmer

$\ln(p_y)$ = Unit price per output (kg)

α_0 = the coefficient accounting for the fixed Revenue common to all cassava farmers

$\alpha_i \ldots \alpha_N$ = the parameter of each input ($p_1 \ldots p_7$) estimated in the revenue function

α_{ij} = the parameter of the symmetry and interaction terms applicable to the revenue function

α_8 = Parameter estimate for output price

$X_1 \ldots X_k$ = Production inputs (like Stem cuttings, fertilizers, land, tools, labors and so on)

ln = Natural Logarithm to the base e

v_i = two-side normal error term with mean zero and constant variance

u_i = one-side truncated normal error term of inefficiency from cassava farmer

The inefficiency determinants were derived from joint estimation with equation 3.1 and 3.2 from which the technical and allocative efficiency score of i^{th} farmers were predicted. Determinants of inefficiency were specified as:

$$\mu_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + \delta_9 Z_9 + \delta_{10} Z_{10} + v_i \quad \ldots\ldots (3.4)$$

μ_i = is the inefficiency score of the cassava farmers (as stipulated in 3.2 for technical efficiency and 3.3 for allocative efficiency)

δ_0 = is the level of technical inefficiency constant among all cassava farmers

$\delta_1 \ldots \delta_9$ = the parameters (coefficients) to be estimated

v_i = is the stochastic normal (two-sided) error terms

Z_1 = Age of the cassava farmer

Z_2 = Gender of the cassava farmer (1 = female, 0 = male)

Z_3 = Farming Experience of the cassava farmer

Z_4 = Educational level of the farmer (years of formal schooling)

Z_5 = Household Size (number of members in the farmer household)

Z_6 = Location of farm (proxy for region: 1 = Bomi, Nimba = 0)

Z_7 = Farm group membership (1 = membership, 0 = otherwise)

Z_8 = Access to Agricultural Credit (1= yes, 0 = otherwise)

Z_9 = Access to extension contact (number of extension visit received)

Z_{10} = Farm distance to input market (access to market)

3.3.2 Estimation of the Economic Efficiency

Empirical models are used to simulate a measure for policy discussion and to present the relationships of actual scenarios from the measurement of the abstract relationships between variables (Debertin, 2012). Hence, the study adopted the stochastic frontier (SF) models to estimate the technical and output-allocative efficiencies of cassava production. This model is preferred because it treats inefficiency as a content of a composite error. This great virtue of the SF model enables the separation of the stochastic shock from the variation of the inefficiency term, and provides a reliance for statistical inferences (Kumbhakar & Lovell, 2000; Coelli *et al.,* 2005).

The generalized Translog type of function was used to represent the production and revenue functions because it is adequate for real-world production function with more than two inputs, and it permits a greater variety of substitution and transformation patterns to deal with the limitation of the Cobb-Douglas functional form. Also, its logarithms transformation provides linearity to easily estimate the parameters of real-life functions (Christensen *et al.,* 1973).

The one-step joint maximum likelihood estimation (MLE) was performed to attain estimates of production along with determinants of the technical and allocative inefficiency, and the revenue estimates along with determinants of the allocative inefficiency respectively. Then, the technical and allocative efficiencies scores were predicted from the production and revenue function respectively. The joint MLE ensures that the effect of the inefficiency across each of the factors is accessed only once. Also, the MLE procedures derive estimates that are virtually always consistent, asymptotically efficient with normally distributed errors for a large sample (Coelli *et al.*, 2005).

3.3.3 Estimation of the Metafrontier Technical Efficiency

The meta-frontier indicated as ${f_t}^M(X_{ijt})$, that is associated with each of group production functions from farmers in the region of Bomi and Nimba, estimated in equation 3.2, is only defined if it envelops each region-frontier. The meta-production function must fit and qualify as an overall production function containing all of the production resources of all the "j" regions, such that the lagging of each region's technology from the meta-frontier function is greater than or equal to zero. This lag between the region's optimal frontier and the metafrontier is referred technology gap ratio (TGR). It accounts for the composite shocks of the stochastic errors inflicted from region's estimates and all other non-stochastic affecting determinants of the meta-frontier (also called the environmental factors). This relationship of the metafrontier to the environmental factors is given as follow:

$$f_t^{M}(X_{ijt})e^{-U_{ijt}^{M}} = f_t^{f}(X_{ijt}), \quad \text{where } U_{jit}^{M} \geq 0 \quad \text{......................} (3.5)$$

To measure the inefficiency of the environmental determinants, the technology gap ratio (TGR) is the predicted score used to explain each region's level of efficiency to the metafrontier. TGR_{it}^{j} is thus predicted as follow:

$$TGR_{it}^{j} = \frac{f_t^{j}(X_{ijt})}{f_t^{M}(X_{ijt})} = e^{-U_{ijt}^{M}} \leq 1 \quad \text{..........................} (3.6)$$

By predicting this gap for each region, given as TGR_{it}^{j}, it becomes easier to measure a firm's efficiency relative to the meta-frontier. This efficiency level, called Metafrontier Technical Efficiency (MTE) is determined as the product of a firm's technical efficiency (TE) and the region's TGR as:

$$MTE_{ijt} = \frac{Y_{ijt}}{f_t^{M}(X_{jit})e^{V_{ijt}}} = \frac{f(X_{ijt})}{f_t^{M}(X_{jit})e^{V_{ijt}}} = TGR_{it}^{j} * TE_{it}^{j} \quad \text{.................} (3.7)$$

Where TE_{it}^{j} is the technical efficiency of an "i" firm over time "t" within-region "j.

From these generated statistics, the TE, TGR, and MTE are compared to inferred options for managerial decision-makers at firm levels and policymakers are regional and national levels.

3.4 Description of the Study Area

The study was implemented in two counties, Bomi and Nimba, within Liberia. The Liberia agriculture sector is profiled into six (6) agro-clusters, based on crops and growth advantaged. The Study areas fall within two of the three cassava cultivating agro-clusters; they are: the western corridors, the Nimba cluster and the south-eastern clusters (Zinnah, 2016).

Bomi has four (4) administrative districts and lies in the north-western region of Liberia with the western cassava corridors. Bomi borders Montserrado County, within which lies the national capital city, Monrovia. Bomi has a land area of 755 square miles, a population estimate of 84,119 persons, with seventy percent of its active workforce engaged within the agriculture sector (LISGIS, 2009). The county has an average yearly rainfall of 80mm, and an ideal sandy clay-soil (GOL, 2012a). Bomi is a food-insecure county with average food-expenditure proportion equivalent to sixty-nine percent on income (WFP, 2013;2015). In Bomi, cassava is mostly processed into local food products, like fufu and gari; and mostly consumed by the majority of the inhabitants.

Nimba is located in North-eastern Liberia. It hosts international borders with the Republics of Guinea and Cote D'Ivoire. Average rainfall in Nimba falls within 12.5mm to 300mm during both rainy and dry seasons. Nimba county has the largest portion of latosol, the best soil type ideal for agricultural purposes (GoL, 2012b). From the latest National Census (LISGIS, 2009), Nimba has seventeen (17) administrative districts, with a population estimate of 462,026. According to the latest crop estimates, Nimba had the largest cassava farming households of 26,530 farmers, with many small-scale farmers. The county contributes the largest portion (of 26.6 percent) to the national cassava output aggregate (MoA-RL, 2009). Both of these locations are more than 300 kilometers apart, shown in Figure 1.3.

Figure 3.3: Political sub-division of Liberia (Study Areas shaded green)

3.5 Sampling procedure

The study used a multi-stage sampling procedure to determine the sample. In the first stage, a purposive sampling procedure was used to select Bomi and Nimba because cassava is mostly produced and processed respectively in these counties. In the second stage, purposive sampling was used to select specific administrative districts (four from Bomi and five from Nimba) where cassava cultivation is most intensive. In the third stage, a systematic sampling procedure was used to select farmers from the districts selected in the previous stage.

3.5.1 Population

The study is focused on all cassava farmers in Bomi and Nimba counties. The total agriculture population of 1.56 million is dispersed into 274,070 agriculture households (MoA-RL, 2009). Of this population, 49.9 percent are female farmers even though two-thirds of the agriculture households are headed by males. From the agriculture population, approximately 75 percent of agriculture households cultivate cassava regardless of whether they plant other crops (LISGIS-RL, 2017).

3.5.2 Sample Size

The sampling frame covered all cassava farming households within the study areas of Bomi and Nimba. According to MoA-RL (2009), there are 30,840 total cassava farming households in the study areas. From these statistics, 26,530 are residents in Nimba (cultivating 13,530 hectares), and 4,310 households are in Bomi counties (cultivating 2,200 hectares). The sample frame, covering cassava households from the two counties, constitutes 26 percent of the total estimate of cassava cultivating households in Liberia. Using this sample frame, the sample size was determined from Kothari's (2004) estimator for a proportion of a finite population. The estimator of a sample size for a large finite population is given by:

$$n = \frac{Z^2 * P * Q * N}{e^2 * (N-1) + Z^2 * P * Q} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.8)$$

Where n is the sample size, Z^2 is the critical (abscissa) value under the normal curve for which the population distribution is true to the sample given by $\propto$; *e* is the desired level of precision of the researcher; *P* is the sample proportion of cassava farmer in the study area compared to cassava cultivating households (estimated within GoL, 2009); *Q* (equal to 1-P) is the difference in attributes of the proportion from the sample frame, and *N* is the total number of cassava farmers in the study area (which is the total sample frame of the study). According to Kothari (2004), "the proportion of the estimator is determined in two way: either by taking a conservative value of P = 0.5; or to estimate the proportion based on personal judgment or a pilot study with the observation of 225 or more observation a reasonable approximation of the P-value."

Given a frequently use precision level of e = ± 0.05, and level of significance, $\propto = 0.5$ (which is 95% confidence interval where Z = 1.96), P = 0.26 (the proportion of 30,840 cassava farmers to 117,730 total cassava farmers from a past study: the crop estimate by the Government of Liberia), and Q = 1-P = 0.74,

The sample size for the study is determined using equation 3.8 as follow:

$$n = \frac{Z^2PQN}{e^2(N-1)+Z^2PQ} = \frac{(1.96)^2(0.26)(0.74)(30{,}840)}{(0.05)^2(30{,}840-1)+(1.96)^2(0.26)(0.74)} = \frac{22{,}794.58}{77.84} \approx 293$$

According to Israel (2012), the sample size derived from estimators is mostly lower than the proposed sample size because the researcher should consider on-field uncertainties including unreached contacts and non-respondents. Hence, to compensate for field uncertainties, 10% (28 samples) and 20% (58 samples) were added to account for unreached contacts, and non-respondents respectively. Hence, the total sample size was three hundred eighty (380).

3.5.3 Sampling

Participants for the study were sampled from the four administrative districts of Bomi, and the five administrative districts selected in Nimba counties respectively. The selection was based on the list of cassava farmers[3]. From Bomi, the list included 777 cassava farmers from the four districts, while the list from Nimba had 3,128 cassava farmers from the five selected districts. The lists were joined, and a systematic interval of ten[4] was used to select the participants. The list of farmers was adopted, rather than the on-site systematic selection, because of scattered housing and farm arrangements; and due to shifting practices and the deplorable road conditions to access some locations during the rainy season when the data was collected.

3.6 Data Collection

The study utilized primary and secondary data. Primary data were collected from farmers. Nine (9) enumerators were recruited from within the study areas to collect the data from farmers in Bomi and Nimba counties. The questionnaires and collection schedules were tested in Nimba

[3] The farmer list from Bomi was obtain from the Ministry of Agriculture county office; and the farmer list from Nimba was obtained from the Liberia Agriculture Development Activity (LADA) county office.
[4] The sum of the lists (N) was divided by the determined sample size (n): N/n

after the enumerator training sessions. Feedbacks were received and incorporated into a final set of questionnaires that was used to collect data from participants. Using tablets and phone installed with the KoBoToolbox® collection kit, enumerators collected primary data using soft questionnaire and schedules that were automatically uploaded when enumerators accessed internet connections. Enumerator collected data on farm inputs, cassava outputs, inputs and output prices, farmer socio-economics (and demographic) characteristics, and institutional determinants related to cassava farming and farmers. From the 380 participants proposed in the study, 371 farmers were reached. Five of the respondents could not be reached due to financial constraints, and limited time for data collection. Four other farmers traveled from their farms and did not return within the period set for data collection

3.7 Diagnostic Tests

Before progressing with the analyses for the objectives, pre-estimation tests were done on the data. Variables were reviewed using exploratory analysis and diagnostics tests. It is improper for an applied researcher to just select and use a model without actually reviewing the nature of the data to inform adequate models specification and estimations (Mukherjee *et al.*, 1998).

3.7.1 Test of Normality:

The Shapiro Francia test for non-normality was used to provide statistical evidence about the nature of the variables' distribution. The Shapiro Francia (W') statistic tests the null hypothesis (H_0) that the data were collected from a normal distribution. The W' revolves around +1.0, with lower values indicating non-normality of the variable's distribution. W' is a better normality test because it measures the straightness of the variable plot of the normal density and its critical values for normal distribution can be explicitly determined within an interval of 0.9860 and 0.9981 inclusively (Royston, 1983). The test value of the Shapiro Francia for gender, level of education, and access to credits seemed to satisfy the condition for normality because their W'-value fall within the critical interval. Yet, their p-vales were statistically irrelevant at the 1%, 5% and 10% significant levels. Moreover, these variables including age, group membership, and access to extension services are categorical/ordinal and not continuous variables. Hence, they are not suitably explained by the probability concepts of normal distribution. Otherwise, the W' for all the other variables fall outside the interval (see Appendix 1). Based on these, most of the variables were transformed to approximate their distributions to the normal distribution curve. Also, the inefficiency component of the composite errors was assumed to follow a truncated-normal distribution.

3.7.2 Tests of Independence and Associations:

Because of the different types of variables and their different measurements, relationships and associations of pairs of categorical and factor variables were tested by the contingency chi-square statistics of independence (χ^2 or Chi2) and the Cramer's V statistic for associations. Chi2 tests the null hypothesis that the variables are independent of one another. However, statistical computer programs normally provide statistics for the alternative hypothesis that variables are interdependent[5] (Mukherjee *et al.,* 1998). The Cramer's V statistics extend the test of linear association on a pair of interdependent variables. The values of the Cramer's V statistic fall inclusively in the interval of zero and one, with higher values nearer to one indicating a higher degree of association and stronger correlation among the pair of variables. The four pairs of variables, "gender and level of education", "gender and marital status", "level of education and years in school" and "access to extension and access to credits", had Cramer's V statistics greater than 0.25. More importantly, the pair "access to extension and access to credits" had the highest Cramer's value of 71 percent, which is the only value Cramer's V stat greater than 50% (See Appendix 1).

[5] STATA tests the hypothesis that that the critical values are larger than calculated Chi2 values. Hence, the probability of the Chi-square value for $\chi2 \leq 0.05$ or ≤ 0.01 means the null hypothesis of the program is rejected at 5% and 1% respectively. Otherwise, "fail to reject" the null hypothesis.

3.7.3 Test for the presence of Multicollinearity:

To test the association of the explanatory (continuous) variables for the presence of multicollinearity, the variance inflator factor (VIF), and the Spearman correlation matrix were used. As a "rule of thumb," a VIF above 10 raises concerns about the presence of sufficient multicollinearity between the variables. The spearman correlation is an ideal method to measure the monotonic association of continuous data, and for data with relevant outliers. The Spearman correlation uses the rank of the variable's values to determine a continuously increasing (or decreasing) association of the variables toward +1.0 (or toward -1.0). (Schober *et al.*, 2018). The mean VIF of 1.74, with individual values varying from 4.33 to 1.08 indicates limited collinearity of the variables. The only correlation value of more than 0.5 is linked to "level of education and years in formal school". Hence, one of the variables was always used in estimation to represent both variables. The rest of the spearman correlation values are less than 0.50. (See Appendix 1).

3.7.4 Test for Heteroscedasticity*:*

The Breusch-Pagan-Godfrey test was used to check the variance of the error term for the fitted variable. The *hettest* tested the hypotheses that:

$$H_0 = \text{constant variance},$$

$$H_1 \neq \text{constant variance}$$

The calculated Chi2 value of 32.10 (p>Chi2 = 0.000) indicates that the alternative hypothesis (H_1) value is within the probability area for which we "fail to reject" the null hypothesis. Hence, it is a reliable conclusion to rule out the presence of heteroscedasticity.

3.7.5 Test of Parameters Stability in the Dataset*:*

With data collected from two different locations, the First Chow test was used to test the stability and linearity of the parameters in the data subsets from Bomi and Nimba counties. The first Chow tests the following, that:

$H_{0:}$ The parameters of the data subsets are equal (stable and linear)

$H_{1:}$ The parameters of the data subsets are different (unstable and non-linear)

Using sex, group membership, access to credits, extensions and the region as the variables to test the equality of parameters, the calculated values of F=0.49 (p>F = 0.7463) indicated, that the probability curve for the stability of the parameters within the datasets is beyond the region of the null hypothesis. Hence, the null hypothesis was rejected, with the conclusion that the parameters of the data subsets are unequal. Therefore, it was appropriate to treat the data subsets, of Bomi and Nimba, separate during estimation and analysis.

3.7.6 Test for the adequacy of inefficiency model specification:

The generalized likelihood ratio test (GLR) statistic was computed, using the formula: GLR = $[-2(LH_0 - LH_1)]$ to test that:

H_0 : There is no significant inefficiency component within the error term

H_1: There is a significant variation caused by an inefficient error component

The general likelihood statistic is better for model fitting because it is asymptotically optimal when comparing convergence of models (Fan *et al.*, 2001). The critical Wald statistics in Kodde & Palm (1986) for the joint tests of model equality are adequate values to determine the significance levels for hypothesis testing of mixed distributions (Kumbhakar *et al.*, 2015). With thirteen degrees of freedom (df=13), the calculated GLR statistics for the Translog and Cobb-Douglas functional forms are 47.95 and 52.74 respectively. Comparing these values with Kodde & Palm (1986) critical values = 33.823, df=13, and P=0.001, the null hypothesis was rejected; with the conclusion that there is a significant inefficiency component of the error term, which can be better analyzed by the stochastic frontier model of either the Cobb Douglas or the Translog functional form.

3.7.7 Test for the selection of the functional form (Cobb Douglas or Tran-log):

Each of the functional forms was estimated on the pool and data subsects. Linear post estimation test and the Lambda coefficient (λ) were used to determine the functional form. The Cobb-Douglas was tested on the linear hypothesis that the sum of the marginal productivity of the inputs equals one; while the Translog's interactive and squares variables were tested to be insignificant (equal zero).

From the estimation and the linear post-estimations tests, the Translog functional forms performed better than the Cob-Douglas for the pool and data subsets. The 1% significant lambda value of 3.67 on the Bomi dataset, and the significant 5% lambda value of 0.94 on the Nimba dataset of the Translog functional form are better than the corresponding counterparts of the Cobb-Douglas function form as shown in the summary table below. On the basis of these diagnostics tests, the objectives of the study were analyzed in the succeeding chapter.

Summary table of the Lambda Coefficients and the Linear Tests Output

	Cobb-Douglas			Translog		
Data set	Chi2 (1)	p > Chi2	Lambda (λ)	Chi2 (21)	p > Chi2	Lambda (λ)
Bomi	0.01	0.92	0.31	79.91	0.00	3.67
Nimba	2.54	0.11	0.69	39.93	0.01	0.94
Pool	2.74	0.10	0.77	40.99	0.01	0.92

Source: Author Survey data computation, 2019

3.8 Data Management and Analysis

3.8.1 Data Management

From the online KoboToolkit® server unto which the completed questionnaires were uploaded from the field, the data was downloaded and stored in Microsoft Excel spreadsheets.

3.8.2 Data Analysis

Data analysis was done based on the specific objective of the study: to characterize cassava farming, determine the economic efficiency and the metafrontier technical efficiency of cassava production in Bomi and Nimba counties, Liberia.

Stata 14.2 and Microsoft Excel spreadsheets were used to analyze the data. During preliminary reviews, variables were generated and some were recoded to clean the data. During this process, 68 observations were dropped from the dataset due to the loss of information on some key variables. Three hundred and three (303) observations were used to characterize cassava production in Bomi and Nimba, and to assess the hypotheses of the study, that:

Ho: Smallholder cassava farmers in Bomi and Nimba *are not* economically efficient;

Ho: Cassava farms in Bomi and Nimba counties *are not* fully utilizing the capacity of available inputs in the cassava sub-sector.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter contains the results and discussion of the study. The result emanates from the estimations of separate stochastic production and revenue frontier models of the Bomi and Nimba data subsets, and the estimation of the stochastic meta-production function of the pooled data set.

4.1 Characterization of Cassava Farming and Farmers

Descriptive statistics sketch a summary of what the dataset is really like by using few references, usually the measure of central tendency and measure of variability. According to Bakeman & Robinson, (2005), an ideal way to describe a dataset is to present the descriptive statistics in tables, charts, graphs, and figures in order to compare and explain the observations.

4.1.1 Bomi County

Farmers descriptive and characteristics of cassava farms in Bomi County are presented in Table 4.1. From the result, the mean age of a cassava farmers is 44 years, is found within the age range from 22 years to 87 years. The mean cassava farming experience is 16 years, with farmers having up to fifty years in cassava cultivation. An average cassava household has six persons, with an average farmer having a maximum of six years in the formal education school system. This indicates that farmers in Bomi either have education level within primary division or are principally illiterate. The average distance of a cassava farm to the nearest market is 9.6 kilometers, indicating a challenge for farmers to access inputs especially when they are needed. The mean cassava farm is 3.89 acres[6], from which an average of 1,188.51 kilogram of tubers are harvested, even though productivity vary from 100 kilogram to 6,000 kilograms of cassava tubers from an average cassava farm. In Bomi, a cassava farmer uses an average of 29 bundles

[6] Conversion of land: 1 acre = 0.41ha

of cassava stems, 3 pieces of hoes, 3 machetes, 22 man-days from male laborers, and 9 man-days efforts from female labors through the cassava production chain. The average income from cassava output of L$28,706 falls within the revenue brackets of L$2,375 and L$168,000 inclusively.

Table 4.1: Cassava farmer and the farm characterizations in Bomi County

(n = 87)

Variable	Mean	Std. Dev.	Min	Max
Cassava Output (kg)	1,188.51	1,020.38	100	6000
Farm size (acres)	3.89	2.46	1	14
Stem (bundles)	28.86	23.95	0	150
Machete / Cutlass (pcs)	3.06	2.93	1	25
Digging Hoe (in pcs)	3.34	3.03	0	25
Male Labor (man-day)	21.53	12.26	4	60
Female Labor (man-day)	8.34	8.53	0	51
Age of farmer (years)	44.63	14.14	22	87
Farming Experience (years)	16.26	11.29	2	50
Household Size	6.75	2.78	1	15
Level of Education	3.56	0.89	1	6
Farm to Input markets (km)	9.63	12.89	1	72
Cost of land [7] (L$/acre)	146,756.70	168,987.70	0	970,000
Price of Stem (L$/bundles)	271.60	265.64	0	1,467
Price per Machete (L$/pc))	715.34	434.44	0	2,000
Price per hoe (L$/pc)	462.89	414.17	0	1,550
Average wage (L$/ man-day)	324.17	168.88	100	1,233
Land Prep wage (L$/ man-day)	321.64	108.88	0	750
Planting wage (L$/ man-day)	302.93	142.18	0	1,000
Weeding wage (L$/ man-day)	347.93	414.38	0	3,000
Average cassava price (per kg)	25.07	12.64	8	70
Revenue (L$ per output)	28,706.03	28,742.56	2,375	168,000

[7] The proximate costs of land were collected in US dollar converted to Liberia Dollars (L$) at the mean approved rate from the Central Bank of Liberia during data collection. 1 US$ = 194 L$.

Source: Author's computation from data, 2019

4.1.2 Nimba County

Table 4.2 presents the descriptive statistics cassava farms and farmers in Nimba County. The mean age of cassava farmers is also 44 years, but with range between 16 and 80 years. An average cassava farmer has four years in formal education, and a mean of ten years cassava experience in the cultivation of cassava.

Table 4.2: Cassava farmer and the farm characterizations in Nimba County

	(n= 216)			
Variable	Mean	Std. Dev.	Min	Max
Cassava Output (kg)	1,506.02	1,413.24	75	10,000
Farm size (acres)	3.34	2.64	1	30
Stem (bundles)	43.63	30.80	3	200
Machete / Cutlass (pcs)	3.64	2.23	0	22
Digging Hoe (in pcs)	4.19	2.98	0	32
Male Labor (man-day)	22.66	15.81	0	80
Female Labor (man-day)	20.78	13.79	0	65
Age of farmer (years)	44.20	13.41	16	80
Farming Experience (years)	10.08	8.31	1	48
Household Size	9.23	3.98	3	28
Level of Education	3.99	0.78	3	6
Farm to Input markets (km)	5.59	5.12	1	42
Cost of land (L$/acre)	273,315.50	366,937.90	0	2,910,000
Price of Stem (L$/bundles)	122.29	157.61	0	1,500
Price per Machete (L$/pc))	690.56	231.04	0	1,700
Price per hoe (L$/pc)	479.57	513.24	0	3,750
Average wage (L$/ man-day)	196.48	58.14	43	567
Land Prep wage (L$/ man-day)	213.17	93.26	50	1,200
Planting wage (L$/ man-day)	190.31	60.90	0	500
Weeding wage (L$/ man-day)	185.97	76.37	0	850
Average cassava price (per kg)	21.15	15.64	4	90
Revenue (L$ per output)	26,030.59	24,254.24	900	156,250

Source: Author's Computation from Data, 2019

In Nimba, the average household size contains nine persons; the mean distance of a farm to market access is 5.59 kilometers away. A mean cassava farm measures 3.34 acres on which a mean of 44 stem bundles, 4 machetes, 4 hoes, 23 man-day efforts from male labors, and 21 man-day efforts from female labors are used to produce an average output of 1,506 kilograms. The mean revenue of cassava output in Nimba is L$26,030, and fall within the range of L$900 and L$156,250 inclusively.

4.1.3 Pooled Dataset of Bomi and Nimba Counties

The descriptive statistics of the cassava subsector containing the pooled dataset of Bomi and Nimba counties are summarized in Table 4.3, Table 4.4, Figure 4.1, and Figure 4.2.

Table 4.3 compares the statistical means of the variables in datasets, and indicates where applicable the level of statistical difference between the means. From the result, the variables with similar statistical means are: the age of the cassava farmer, the number of male man-day efforts used by the farmer, the prices of machetes and hoes, and the revenue of cassava output. It implies that these variables have similar characteristics and effects across regions. Hence, their mean effects on farmers in one of the regions during analysis can be safely inferred on farmers in the other region. For example, the mean age of the cassava farmers is the same 44 years in Bomi or Nimba County; the prices for hoe and machetes are not statistically different, so when farmers are buying machetes and hoes, they are indifferent about their prices in the regional markets.

The rest of the means for the other variables have statistical different regional means. This means that their effects are region specific, and it is infeasible to generalize the effect of a mean in one region to the other region. For example, at 10% significance level, the average output of the subsector is 1,406.69 for the pooled data; but, Bomi farms indicate a mean output of 1,188.51 kilograms and Nimba farms have a mean of 1,506.02 kilograms. Also with a subsector mean of 39 stem bundles, there are glaring differences in the mean bundles of cassava stems farmers used in Bomi (28 bundles) and Nimba (43 bundles); and the mean sectoral cassava farming experience of 12 years is lower than the average farmer's experience in Bomi (with a mean of 16 years), and higher than farmers in Nimba county (with mean experience of 10 years).

Table 4.3: Comparison of the regional means to the pooled means (two-way T-test)

	Means			
Variable	Pool (n = 303)	Bomi (n = 87)	Nimba (n = 216)	t - statistic
Cassava Output (kg)	1414.85	1,188.51	1,506.02	-1.91*
Farm size (acres)	3.49	3.89	3.34	1.67*
Stem (bundles)	39.39	28.86	43.63	-4.01***
Machete / Cutlass (pcs)	3.48	3.06	3.65	-1.89*
Digging Hoe (in pcs)	3.95	3.34	4.19	-2.23**
Male Labor (man-day)	22.33	21.53	22.66	-0.59
Female Labor (man-day)	17.21	8.34	20.78	-7.83***
Age of farmer (years)	44.32	44.63	44.20	0.25
Farming Experience (years)	11.85	16.26	10.08	5.26***
Household Size	8.51	6.75	9.23	-5.32***
Years of formal schooling	5.92	4.08	6.67	-3.85***
Level of Education	3.86	3.56	4.00	-4.14***
Farm to Input markets (km)	6.75	9.63	5.59	3.91***
Cost of land (L$/acre)	236,976.8	146,756.7	273,315.5	-3.09***
Price of Stem (L$/bundles)	165.16	271.6	122.28	6.04***
Price per Machete (L$/pc))	697.67	715.34	690.56	0.64
Price per hoe (L$/pc)	474.78	462.89	479.57	-0.27
Average wage (L$/ man-day)	233.15	324.17	196.48	9.78***
Land Prep wage (L$/ man-day)	244.31	321.64	213.17	8.72***
Planting wage (L$/ man-day)	222.65	302.93	190.31	9.66***
Weeding wage (L$/ man-day)	232.47	347.93	185.97	5.53***
Average cassava price (per kg)	22.27	25.07	21.15	2.08**
Revenue (L$ per output)	26,798.79	28,706.03	26,030.59	0.8225

*, **, and *** indicate 10%, 5% and 1% significance difference levels respectively
Source: Author's Computation from Data, 2019

From Table 4.3, the mean cassava farm size for the pooled data is 3.49 acres (approximately 1.41 hectares), with regional farm sizes of 3.89 and 3.34 for Bomi and Nimba datasets respectively. This illustrates that many of the cassava farmers are small-scale farmers cultivating farm plots of 2 hectares or less (Rapsomanikis, 2015). Also, the mean household size for the cassava subsector has 8 persons, compared to the regional household sizes containing 6 and 9 persons in Bomi and Nimba datasets respectively. The significant difference between household means can be explained by the farmer's settlements. In Bomi, cassava farmers lived in mostly peri-urban communities, whereas cassava farmers in Nimba reside in rural communities with basic farming activities, and lower structural development.

The mean year of formal education for the pooled dataset is 6 years; with the regional means of 4 years and 7 years respectively for farmers in Bomi and Nimba counties. In Liberia, the educational system comprised of nine classes within the primary level, and six classes within the secondary level. Hence, the result indicates that most of the farmers have basic primary level education or they are fundamentally illiterate.

The average cassava farming experience is 12 years for the pooled dataset, 16 years for the Bomi dataset, and 10 years for the Nimba dataset. Experience entails continual and persistent use of recent planting materials and experimental practices that have been approved on farmer demonstration sites. Farmers repugnant to new technology and improved practices do not increase farming specific experiences regardless of the farmer's age (Ainembabazi & Mugisha, 2014; Stuiver *et al.*, 2004). Hence, the statistical differences of the farming experiences can be attributed to the geographical locations, the level of formal education, and the adoption level of extension services. Cassava farmers in Bomi County have higher access to, and adoption of extension services. Demonstration plots are popular in Bomi for famers to test stem varieties and farming practices before adopting.

Land cost and wages account for the highest production cost in cassava cultivation. However, many cassava farmers inherited farmland, or they are offered land on customary practices to farm cassava. At the 1% significance level, there is a meaningful difference between the mean per acre cost of land at L$236,976.80 for the pooled data, L$146,756.70 (approx. US$756.48) for an acre of land in Bomi and L$273,215.50 (approx. US$1,408.33) for an acre of land in Nimba. The low cost of land in Bomi is linked to the belief of land as the family legacy. Within some areas in Bomi, land sale (or lease) is unthinkable and customarily unacceptable. Hence, some farmers reported no cost for farmland they inherited, or land they were offered as a gift (to farmers who are without land or who decided to plant in another area) on a condition to reciprocate assistance in the future (Ellis, 1993). In Nimba, there are rapid emergence of structural improvements near farming sites. Hence, these structures elevate the opportunity cost of land to other commercial uses. Therefore, farmlands in Nimba that are adjacent to construction sites, mining areas, and peri-urban cites have higher costs.

With 1% significance difference to the phase within the production chain and the kind of work, the average cost of a man-day effort in the sector is L$233.15. Specially, the mean wages for task during land preparation, planting the cassava stem, and weeding the farms for the pooled datasets are L$244.31, L$222.65, and L$232.47 respectively.

The average price of cassava tubers for the pooled data is L$22.27 per kilogram. Meanwhile, the mean output price in Bomi is L$25.07 per kilograms; while Nimba's average output price is L$21.16/kg. At the 5% level of significance, farmers’ motivations support the variation of output prices in the regional datasets. Cassava output prices in Bomi are higher than those prices in Nimba because, farmers in Bomi seek to earn farm income, while farmers in Nimba cultivate mainly for sustenance and consumption purposes.

From the result in Table 4.4 and Figure 1, seventy-five percent (75%) of the pooled farmers are older than 35 year old. The age pattern of a farmer spans through three stages: the entry, growth, and exit stages. Hence, with majority of the pooled farmers above 35 years, it implies that most of the farmers are either within the "exit phase of age productivity" or they could be experiencing declining age productivity (Tauer, 1984; 1995).

Sixty-one (61%) of the pooled farmers are men; and eighty-one percent (81%) of the respondents indicated that they are not-single[8]. This marital status highlight the importance of cassava to the farmer's livelihood: that cassava farms are either providing food for farmers along with their extended families, or is been used as an income source for livelihood.

Less than thirty percent (< 30%) of cassava farmers within the subsector accessed credit and adopted extension services. This indicates that accessing credit is a challenge to most of the cassava farmers in the subsector. Major challenges to accessing credits are: the complete absence of financial entity in rural areas, the farther-away of financial services away from farms, and high-interest rates on available loans. The low extension adoption result of extension services by Nimba farmers coincides with a result of a previous study by Lah *et al.*, (2018) on the comparison of private and public extension services to cassava farmers in Nimba county.

Seventy-seven percent (77%) of cassava farmers in the subsector do not have membership tides in any farming group. Against expectation, farm group did not tend to support farm labor. Opportunism and free-riding on membership tides by some to acquire labor support only on

[8]For the Marital Status Variable, "Not single" indicates the farmer is either married, stayed together with spouse or relationship is recognized by local traditions. "Single" include widow, widower, a divorced or an officially separated farmer from his/her spouse

their farms, but reneging to contribute labor during other's term, is a major weakening point to the social capital of the group. Hence, many farmers avoided calls to join farming groups.

Table 4.4: Descriptive Statistics for Categorical Variables

Variables	Bomi (n=87) Percent (%)	Nimba (n=216) Percent (%)	Pooled (n=303) Percent (%)
Gender			
Male	63	60	61
Marital Status			
Not Single	76	83	81
Farm's Motivation			
Food	30	74	61
Income	70	26	39
Age Group			
Under 25 years	3	3	3
25-34 years	22	22	22
35-44 years	31	29	30
45-54 years	22	21	21
55-64 years	13	14	14
Above 64 years	09	11	10
Farm group Membership			
No	68	81	77
Main source of Income			
From farm activity	66	93	85
Source of farmland			
Inheriting Land	95	95	95
Access to Extension			
No	43	91	77
Access to Credits			
No	59	76	71
Cropping System			
Mono cropping	37	36	36
Mixed cropping	47	36	39
Mono and Mixed cropping	16	29	25

Source: Author's Computation from Data, 2019

Within the cassava subsector, farmers cultivate cassava plant cassava for either feeding purposes or for income purposes. However, sixty-one percent (61%) of all the farmers in the subsector cultivate primarily for feeding and sustenance purpose. This is a founding basis for national policy to pronounce cassava as a staple, allocate resources its cassava production to mitigate the level of food insecurity in Liberia.

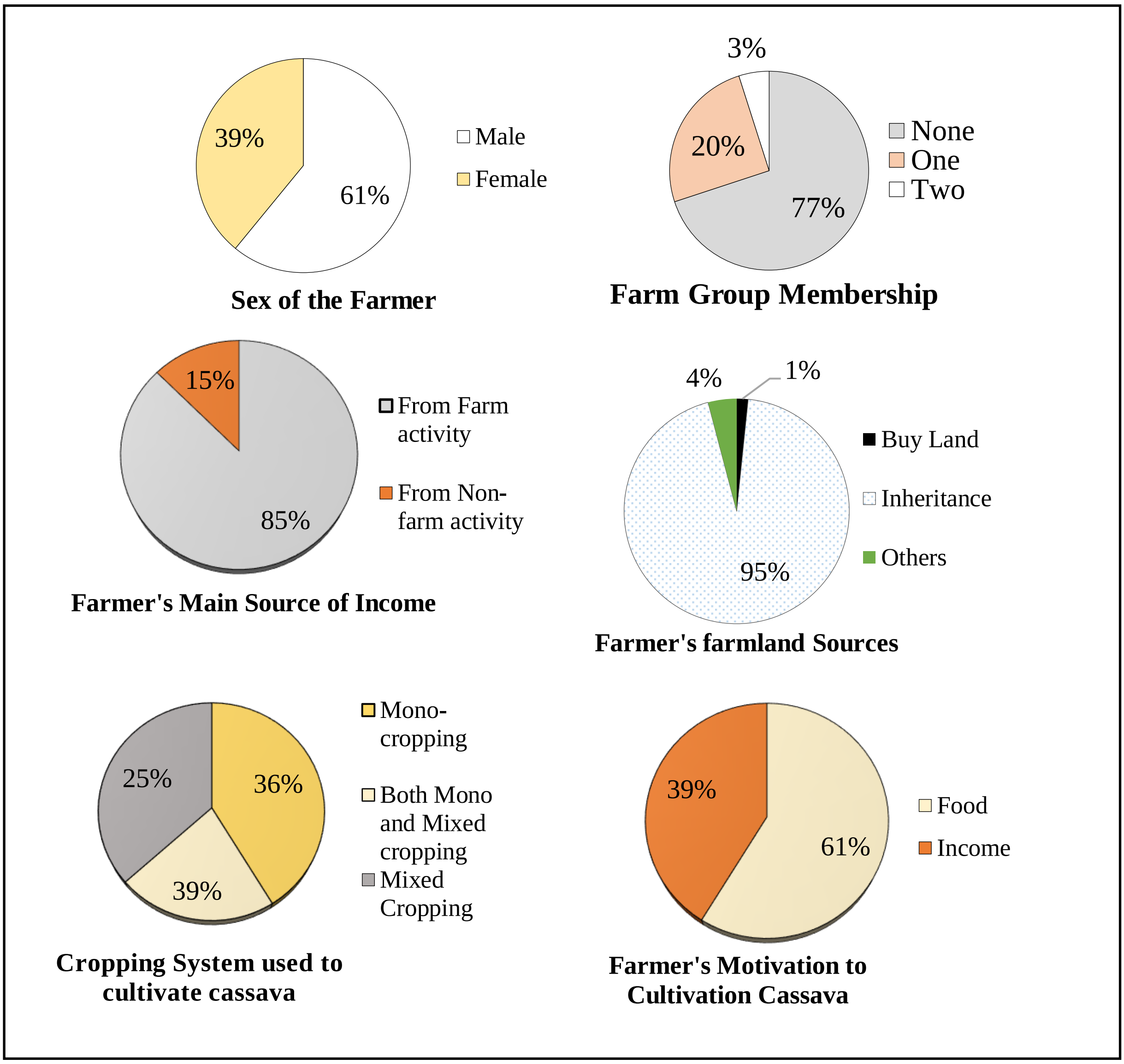

Figure 4.1: Selected attributes of Cassava Farmer in Bomi and Nimba Counties (n = 303)
Source: Author's Computation from Data, 2019

Eighty-five (85%) percent of all the respondents received a major source of income from an agriculture related activity, an indication that a better livelihood of most cassava farmers relies on the viability of the agriculture sector. It is a sector which national government can use to generate employment opportunities for women, youths and other less-fortunate groups and achieve the global goals of decent employment (AfDB, 2016; IFAD, 2016; Nweke *et al.*, 2002).

Within the pooled datasets, ninety-five percent (95%) of the farmers inherited the cassava farmland they are cultivating. With the current Land Right Law already passed into effect in September 2019, the implementation of this act will help to provide land access, ownership, and land use to women and youth to cultivate cassava. Also, community responsibility to use the land for customary and communal purposes, and considering all groups is a good footstep for communities to build consensus upon, and cultivate cassava on public land for feeding and income purposes (GoL, 2019).

Two types of labor efforts and three labor sources were used to employ labor for cassava cultivation. The labor types, male and female efforts, were utilized at all levels of production: land preparation, planting, and weeding stages (Liu & Myers, 2009). Labor during these stages was employed from family, farm group contribution, and hired laborers. Hired laborers dominated the labor efforts used (Figure 4.2a).

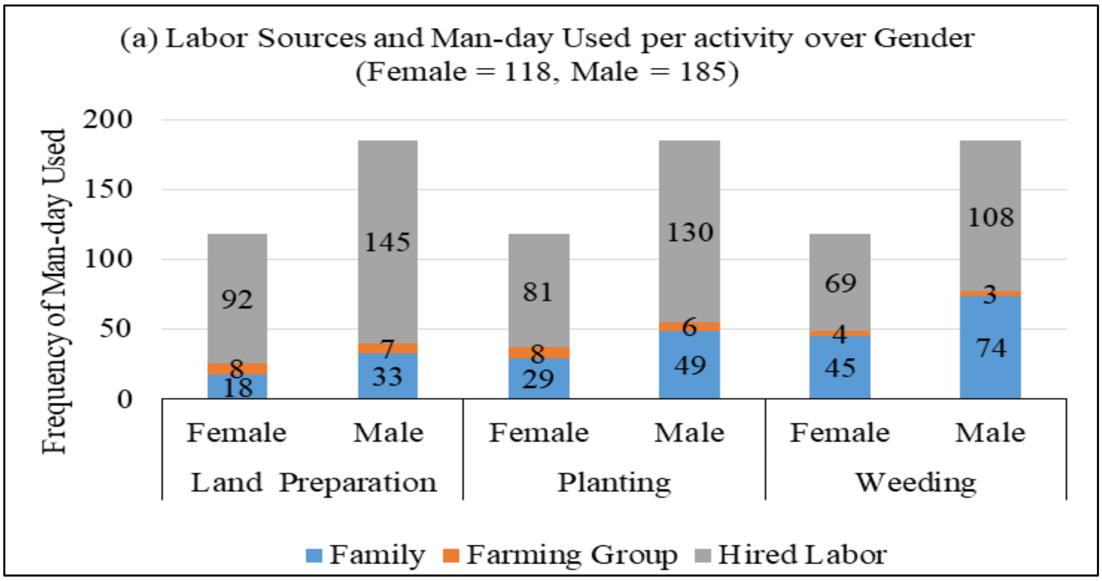

Figure 4.2a: Man-day effort of Labor during the cassava Production stages (n= 303)
Source: Author's Computation from Data, 2019

Shown in Figure 4.2b, more than fifty-five percent of hired laborers were used at all stages of cassava cultivation. During planting and weeding, the proportion of labor efforts (man-days) used from the family source is relatively the same for male and female laborers. As the cassava cultivation progresses from stage to stage, the proportion of man-days supplied from the family labor increases.

Fertilizers and pesticides were superfluous variables. The implication is that the superfluous variables are explained by other factors and including them in the models does not provide additional meaning to the model (Mukherjee *et al*., 1998). Hence, the two variables were dropped because only five of the respondents provided data on the use of fertilizer, pesticide or herbicides.

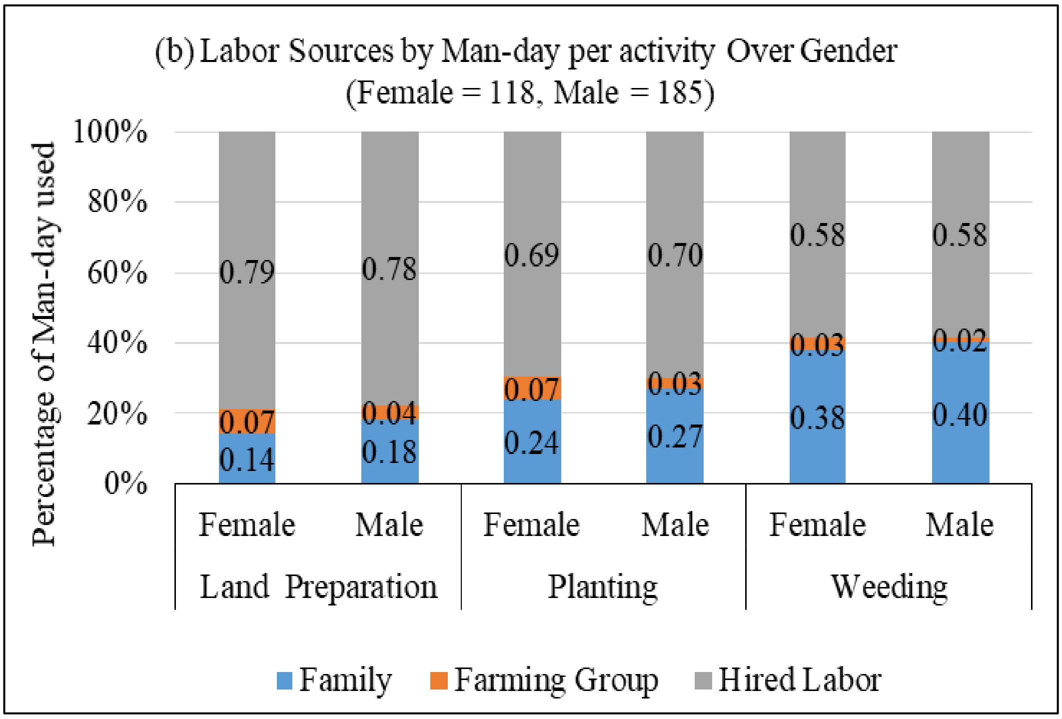

Figure 4.3b: Percent of Labor during the cassava Production stages (n= 303)
Source: Author's Computation from Data, 2019

Also, in Figure 4.2b, the gender's contribution by labor efforts of man-day revealed that proportionately, male and female contributed equivalent man-days efforts at all stages of production. These findings aligns with the results of Nwankwo & Nwaiwu, (2017) and Nweke *et al.*, (2002) that cassava is not a crop attracting only female interests. Different to Nweke *et al.*, (2002) and Nwankwo & Nwaiwu, (2017), women and men share all production activities proportionately and they are not ascribed as he stipulates that men are focused on land preparation while women are assigned weeding, harvesting, and processing roles.

4.2 Determinants of the Economic Efficiency of Cassava Production

To analyze the sources of revenue efficiency[9], separate stochastic frontier models of trans-log production and revenue functions were estimated for Bomi and Nimba counties. Discussions of the determinants of revenue efficiency for cassava farmers in each county are presented.

4.2.1 Bomi County

For Bomi County, the production function and the determinants of the technical efficiency are presented in Table 4.5; and, the revenue function and the determinants of the allocative (output-oriented) efficiency are presented in Table 4.6. In each of the stochastics frontier model's first part, the production or the revenue functions is presented, and the inefficiency models follow in the second part. From the estimation of the Translog functional forms, only the significant squares and interactive variables are presented in this report[10]. The negative signs in the inefficiency models indicate increasing effects of the determinant to the efficiency level, and the positive signs indicate decreasing effects of the determinants to the level of efficiency. However, analyses of the results will follow from the context of efficiency (and not inefficiency).

The estimates of the stochastic production function, the determinants of the technical inefficiency models and the statistics of the composite errors are produced in Table 4.5. At the significant 1%, the values of sigma_μ_1 (0.48) and sigma_v (0.28) are both statistically significant, but the value of the technical inefficiency (μ_1) is higher than that of the random

[9] Revenue Efficiency is an equivalent of economic efficiency with the objective of maximizing revenue given inputs and output prices.

[10] The Trans-log production function has 27 variables: six production factors, six square terms, and fifteen interactive terms. Because of limited space to present the full model, only significant squares variables and interactive terms are included. The other terms are available and can be provided upon a request.

error (v). The higher variation of μ_1 , also reflects in the lambda (λ) values of 1.69, derived from the ratio: **λ = sigma_μ/sigma_ν**. This ratio validates that the standard deviation of the technical efficiency within the composite error is greater than the accompanying standard deviation of the random error.

From the first model in Table 4.5, the production factors of lnfarmland, lnstem, lnmachete, lnhoe, lnmale and lnfemale labors are significant either as a single term or with an interaction. None of the square terms of the Translog was significant at the 0.1, 0.05 or 0.001 levels. At 10% level of significance, four interaction terms of lnfarmland-malelabor, lnstem-hoe, lnmachete-femalelabor, and lnhoe-femalelabor, were significant. At 5% significant level, the variables lnland, lnmachete and lnhoe were significant. The other significant variables at 1% were lnfarmland-stem, lnstem-machete and lnfarmland-stem. The effects of these inputs to the production of cassava in Bomi County vary. For example, the inputs of land and hoe when combined have positive effect on the output of cassava. However, land paired with stem, and land paired with female labor have negative effects; but when paired with male labor, the effect to cassava output is positive. Yet, lnfemalelabor paired with hoe, and the interactions of planting stem with machete have increasing effect on the output of cassava production. This result provides an interesting indication that, farm expansion requires consideration of the farm size-stem ratio. And, cassava farmers and farm managers in Bomi county need to consider the nature of farming tasks (of land preparation), the most efficient efforts (from male labor) and the strategic use of farm tools (machete) to achieve higher cassava productivity. This result aligns with the recommendation of Berhan, (2015) where farm size and seed had negative effects to output, and farmers were cautioned to re-deploy production inputs to rationalize the output of onion.

In Table 4.5, the significant determinants of the technical efficiency effect to the revenue efficiency are age, farming experience, farm-to-market road, group membership, and labor from farm group for planting the stem.

Table 4.5: Bomi Production function and determinants of Technical inefficiency

Variables	Coefficient	Std. Err.	Z-value
Production function: LnCassava Output			
Constant	4.50***	1.40	3.200
LnCassava farmland	1.36**	0.73	1.88
LnStem	-0.14	0.57	-0.24
LnMachete	-2.31**	0.93	-2.490
LnHoe	1.97**	0.90	2.200
Ln Male Labor	0.12	0.80	0.16
Ln Female Labor	0.60	0.50	1.18
LnFarmland-Stem	-0.32***	0.19	-1.660
LnFarmland-Male Labor	0.49*	0.29	1.680
LnFarmland-Female Labor	-0.38***	0.13	-3.040
LnStem-Machete	1.16***	0.32	3.670
LnStem-Hoe	-0.40*	0.23	-1.730
LnMachete-Female Labor	-0.38*	0.20	-1.930
LnHoe-Female Labor	0.27*	0.15	1.820
Inefficiency model: Technical inefficiency ($-\mu_1$)			
Constant	-1.96	1.53	-1.280
Age	0.07***	0.02	3.270
Leve of formal education:			
Primary	-0.39	0.83	-0.460
Secondary	0.09	0.89	0.100
Household size	-0.13	0.080	-1.590
Cassava Farming experience	-0.05**	0.02	-2.580
Farm to market road	0.04***	0.01	2.680
Access to Extension (1 = yes)	0.24	0.32	0.750
Group membership (1 = yes)	0.64*	0.34	1.890
Access to Agriculture credits (1= yes)	0.07	0.29	0.230
Source of Income (1=farm activity)	-0.39	0.33	-1.190
Sources of Labor for Land prep.:			
Farming group	-4.718	3.00	-1.570
Hired	-0.40	0.54	-0.740
Source of Labor for Planting:			
Farming group	5.06*	3.06	1.650
Hired	0.20	0.43	0.460
Source of Labor for Weeding:			
Farming group	-3.09	2.89	-1.070
Hired	0.03	0.29	0.090
Sigma_μ_1	0.48***	0.15	3.180

Sigma_v	0.28***	0.07	4.330
Lambda (λ)	1.69***	0.20	8.290

*, **, *** are values significant at 10%, 5% and 1% respectively

Source: Author's Computation from Data, 2019

Cassava farming experience contributes positively to technical efficiency; age, farm-to-market road, group membership, and labor sourced from the farming group during planting, are negative determinants of the technical efficiency of cassava production in Bomi County.

At the 5% significance level, an additional year of experience acquired by a farmer in cassava farming increases technical efficiency by 0.05. This result implies that, as a farmer accepts quality spill-over information from neighboring farmers, through the application of these ideas, the technical efficiency of the farmer will increase. A cassava farmer who is specific about the type of cassava inputs to use, and is open to learn better information from a neighbor, who had better output in previous years, increased in cassava farming experience. This result aligns with the result of Abdul-kareem & Sahinli, 2018 that farming experience improves the efficiency and profitability of cassava production.

Age accumulates regardless of participation or not. However, cassava is very labor-intensive. Intensive man-day efforts are required at each stage of the production process. By a magnitude of 0.07, an average farmer's technical efficiency decreases as he/she gets a year older. . The negative age effect is in line with similar result of Maina, 2018; but contrary to a parallel study by Nginyangi, (2011) where age had a positive effect. Age productivity follows an inverse-U trend of three stages: labor entry, growth, and exit (Tauer, 1984, 1995). The mean age of farmers is 44 years, with seventy-five percent (75%) of all the farmers over 34 years old, indicates that many farmers are beyond the "energetic" age of 25-34 years; and they are strategically fading out of strength to continue offering intensive labor work on cassava farms. The trend that many of the age are beyond the mean age means that many farmers are leaning toward the exit stage of age productivity. The analysis herein about age also applies to farmers in Nimba County because, there is no statistical difference between the means ages of farmers in Bomi and Nimba counties.

For an additional kilometer, implying a longer distance to access a market, the farmer's technical efficiency will decrease by a magnitude of 0.04. These results show at the 5% significance level, that the farther away a farmer is from accessing cassava inputs, the lower the possibility to even use the inputs in the right way, which leads to a reduction in technical efficiency. This result conforms with the result of the study by Ajayi & Olutumise, (2018) that cassava farm farther away from the farmer's home or the nearest markets tend to have lower technical efficiency.

By a magnitude of 0.64 at the 10% significance level, an additional membership in farming groups decreases the technical efficiency of cassava farmers in Bomi County. A farming group is formed on a temporary, informal basis. Toward farming activities, farming group members supply labor efforts to member farms. However, many farmers free-ride and seek support from the group only to help them, especially during land preparation, but reneging to reciprocate equivalent or better support to other farmers. To this effect, many farmers see membership in the farming groups as a waste of time as it may delay them during brushing, planting, and weeding. The results differ with a similar study by Maina (2018), where farming group membership linked farmers to the access credits and extension services.

Whether a member is in a farming group or not, acquiring an additional laborer from a farming group to plant cassava stems reduces technical efficiency by 5.06. This result highlights the ineffective supervision inherited in unorganized and short-lived farming groups; hence, hiring a laborer under the banner of such farming group increases the risks of improper planting of the stems, and prolongs man-day efforts to the planting phase. This results aligns with the study of Croppenstedt, (2005), where the man-days of hired labor had negative effect on the technical efficiency of wheat farmers in Egypt.

Table 4.6: Bomi Revenue function and determinants of Allocative inefficiency

Variables	Coefficient	Std. Err.	Z-value
Revenue Frontier dependent variable: lnRevenue			
Constant	7.50***	0.59	12.72
Log Cassava farmland	0.11	0.50	0.21
Log Machete	-2.11**	0.83	-2.55
Log Hoe	0.25	0.58	0.43
Log Stem-Machete	0.82***	0.26	3.18
Log Stem-Hoe	-0.22	0.19	-1.20
Log Machete-Female Labor	-0.33	0.20	-1.64
Log Hoe-Female Labor	0.30**	0.15	1.99
Log Average output price	0.93***	0.13	7.37
Inefficiency model: Output-Oriented allocative inefficiency (-μ_a)			
Constant	1.23	2.13	0.58
Age	0.03*	0.02	1.87
Level of Education	-0.18	0.15	-1.21
Marital Status (1=Not Single)	0.05	0.13	0.36
Household Size	-0.05	0.05	-0.90
Cassava Farming experience	-0.04*	0.02	-1.83
Group Membership (1=yes)	0.45	0.33	1.36
Farm to Market distance	0.01	0.01	1.08
Log Average Labor wage	-0.11	0.39	-0.28
Log Stem price	-0.10*	0.05	-1.77
Log Hoe price	-0.10**	0.05	-1.98
Sigma_μ_a	0.43**	0.20	0.03
Sigma_v	0.40***	0.14	0.00
Lambda (λ)	1.07***	0.33	0.00

*, **, *** are values significant at 10%, 5% and 1% respectively
Source: Author's Computation from Data, 2019

The estimates of the revenue frontier, the determinants of the output-oriented allocative inefficiency and the statistics of the composite error are produced in Table 4.6. At 5% level of significance, the value of the standard deviation for the allocative inefficiency term (sigma_μ_a = 0.43) is larger than the standard deviation of the random error (sigma_v = 0.40) at 1% level of significance. The 1% significant lambda (λ= 1.07) validates the dominance of the allocative inefficiency from the estimation. Hence, the model is fit to analyze the revenue function and the determinants of the allocative inefficiency from the stochastic estimation.

Among the estimates of the revenue function in Table 4.6, the positive and significant revenue increasing variables are lnfemale-hoe, lnstem-hoe, and lnstem-machete and lnoutput_price. The significant and revenue reducing variable is lnmachete. The result indicates that planting the cassava stem using a hoe or a machete is an efficient allocative method to increase revenue. Also, employing a female laborer to harvest the cassava tubers using hoe is another allocative method to increase revenue. This is so because women are more caring and careful when they plant, weed, and harvest the cassava tubers. And, an increase in output price will increase revenue from cassava sales. This result is identical with the reviews of the book reviews of Benería & Sen, (1981) that women are responsible for the production of certain crops and solely entitled to the harvest of food crops; it is contrary to the results of Nwankwo & Nwaiwu, (2017) and Nweke *et al.*,(2002), that cassava is not solely a women assigned crop.

The results of the (output-oriented) allocative efficiency determinants contributing to the overall revenue efficiency of cassava production in Bomi County are age, cassava farming experience, the log(price) of the stem, and the (log)price of hoe. Farmer's age has a negative influence on allocative efficiency. Otherwise, cassava farming experience, (log)price of the stem and (log)price of hoe showed positive effects. Log(price) of hoe is significant at 5%, while age, cassava farming experience from cassava farming, and (log)price of the stem are individually significant at 10%.

With a magnitude of 0.03, an additional year to a farmer's age reduces the allocative efficiency of cassava production. With cassava farming been labor-intensive along the production phases, an older Bomi farmer may spend more-days than younger farmers and this reduces the allocative efficiency of cassava production. This result of a negative age-effect on allocative effect is parallel with a similar study of Khan & Saeed, 2011, where age also had negative effect on efficiency of production.

At 10% significance, the allocative efficiency of a Bomi farmer increases by 0.04 for a year of farming experience acquired, regardless of the age of the farmer. From spill-overs knowledge from other farmers, farmers who adopt benefit from advice, how to planting different varieties together, mounding, spacing, and even the depth for planting. Though cost is incurred for acquiring such experience, the revenue emanating from experienced farms are profitable. The quality of cassava output, attracted by market forces, increases the price efficiency of the cassava farmer to generate more revenue. This result corroborates with the finding of Adeyemo *et al.,* 2010 that farming experience increases the profit efficiency of farmers

For ten dollar increase in the prices of cassava stems and price of hoe, farmers' output-oriented allocative efficiency is doubled; the result indicates that cassava stems and hoe can be used as enterprising options to increase farm revenue. Farmer can sell stems from old farmer to Non-governmental organizational (NGOs) that provide input subsidy of cassava stems to cassava farmers in other parts of the country; and hoes can be borrowed to other cassava farmers, during price hike, for cassava tubers during harvest. The traded cassava output can be sold to increase farm income.

4.2.2 Nimba County

The estimates of the Translog production function, the determinants technical inefficiency and the statistics of the composite error terms for cassava farms and farmers in Nimba are produced in Table 4.7. The standard deviation of the technical inefficiency (sigma_μ_2) is higher than the standard variation of the random error (sigma_v). This is validated by the lambda value of 2.00, which shows that the ratio of the variation from the technical inefficiency of the composite error is twice the variation from the stochastic random component. Hence, the model is fitted to analyze the determinants of inefficiency resulting from the use of inputs.

In the result, the estimates for lnfarmland, and the interactions of lnstem-hoe and lnmale_femalelabor are the significant inputs; yet, their effect on the production function is negative. This illustrates that while land, labor, and tools are important for cassava production, the existing production function of cassava farmers in Nimba county is within an infeasible stage (the third stage of the production cycle) where there is a decreasing return to scale that could lead to decrease in marginal output if the trend continues. This is an interesting finding because Nimba is considered as the largest cassava producing county and inputs congestion could be beyond the economic feasible stage. These results support the existence of large cassava farms in Nimba where farmers seemed carefree about the proportion of stem to plant on a farm, the variety of stem to plant, the manner of tool to use, and the type of labor to employ at the various stages of cassava production. This can be attributed due to the low access to and the adoption of extension services by cassava farmers in Nimba County (Lah *et al*., 2018).

Table 4.7: Nimba Production function and Determinants of Technical inefficiency

Variables	Coefficient	Std. Err.	Z-value
Production function: LnCassava Output			
Constant	7.17***	1.80	3.98
Ln Farmland	-1.44**	0.72	-2.01
Ln Stem	-0.20	0.66	-0.30
Ln Machete	0.30	0.78	0.38
Ln Hoe	-0.89	0.85	-1.06
Ln Male Labor	0.56	0.50	1.14
Ln Female Labor	0.58	0.60	0.97

Ln Stem-Hoe	-0.40*	0.22	-1.80
Ln Male - Female labors	-0.20**	0.10	-1.98
Inefficiency model: Technical inefficiency (-μ_2)			
Constant	2.82***	0.69	4.11
Age	0.01**	0.01	2.35
Leve of formal education:			
Primary	0.25	0.37	0.66
Secondary	0.03	0.41	0.06
Household size	0.00	0.02	-0.16
Cassava Farming experience	-0.05***	0.01	-3.75
Farm to market road	0.00	0.01	-0.39
Access to Extension (1 = yes)	-0.66**	0.29	-2.31
Group membership (1 = yes)	0.22	0.14	1.57
Access to credits (1= yes)	-0.08	0.15	-0.50
Source of Income (1=farm activity)	-0.80**	0.35	-2.30
Source of Labor for Planting:			
Farming group	25.25	78.77	0.32
Hired labor	-0.59**	0.26	-2.24
Sigma_μ_2	0.67***	0.09	7.45
Sigma_v	0.34***	0.10	3.40
Lambda	2.00***	0.18	11.43

*, **, *** are significance level at 0.1, 0.05 and 0.01

From the results (see Table 4.7), the age of the farmer has a negative effect on technical efficiency at the 1% level of statistical significance. The positive influencers of technical efficiency are cassava farming experience, significant at 1%. Access to extension, major income from farm activities, and the hired labor for planting cassava stem are also the positive effect determinants significant at the 5% level.

With an added year to a farmer's age, the technical efficiency is expected to decrease by a magnitude of 0.01. While, for an additional year of attained experience from cassava farming, technical efficiency will increases by an effect of 0.05 regardless of the farmer's age. With an acceptable correlations value between the variables, the concept of age productivity (Tauer, 1984, 1995), and the abundance of farmers above the mean age of 44 years, this result indicates that farmers are either approaching or within the exit phase. Hence, they have lower agility to the labor-intensive cassava production. This negative age-effect to technical efficiency, which is a similar result of age in the Bomi county dataset, validates the statistical indifference of the cassava farmers mean age in the regions.

Experienced gained from farming and learning from neighbors over the years are contributed by older farmers to laborers (family or hired) as they engage in the stages of cassava production which improves the technical efficiency of cassava production. This result is similar to the finding of Ogunleye *et al.*, 2014 within which farming experience had positive effects on the efficiency and productivity of cassava production in Nigeria.

Given a farmer who has not accessed extension support, the decision of a farmer to access extension support will increase the technical efficiency of cassava production by a magnitude of sixty-six percent (66%). The implication is that extension service providers are available to assist with the technical know-how of innovations, including techniques and better agronomical practices that will optimize cassava production. This result is consistent with similar to studies on coffee (Lema, 2013) and maize (Mutoko *et al.*, 2015).

For an average cassava farmer in Nimba, who depends on an agriculture crop or activity for the major source of income, adding another agriculture income source will ignite an effect of 0.8 on the technical efficiency of cassava production. The implication is that cassava farmers who diversify into other agriculture enterprises do utilize production inputs for multiple farm tasks. For example, a laborer and tools (including machetes, hoes and planting machines) employed for other enterprises can also be use on cassava farm. Contrary to this result, Mutoko *et al.*, (2015) found that maize farmers with higher education rather diverted to higher non-farm income sources than diversify into more agriculture incomes sources.

With an increasing effect of 0.59, an additional laborer hired during cassava planting of cassava stem increases the technical efficiency of cassava farmers. Many farmers in Nimba cultivate cassava for feeding purposes. Hired laborers are farmers who, after completing their farm works, supply their leisure time to other farmers for wages. Because hired laborers are directly employed to assist in planting cassava cuttings, they treat their contract with a commitment to gain income and to receive further assistance in the future. This behavioral motivation of household labor suppliers, for sustenance and enterprising purposes, is an important characteristic of farm households in the peasant economy (Ellis, 1993).

The estimates of the stochastic revenue function, the determinants of the output-oriented allocative efficiency for farmers in Nimba County, and the statistics of the composite errors are produced in Table 4.8. From the one-step estimation, the sigma_μ_b of 0.62, the sigma_v of 0.38, and the lambda of 1.61 indicate the presence of greater variation of the standard deviation from the allocative inefficiency within the composite error.

The significant variables affecting the revenue function are lnfarmland, lnstem-hoe, lnmachete-malelabor, lnhoe-malelabor, lnmale-femalelabor, and lnOutput-price of cassava.

The positive revenue increasing determinants are lnhoe-malelabor and lnOutput-price. The inputs with negative effects to the level of revenue are lnfarmland, lnstem-hoe, lnmachete-malelabor, and lnmale-femalelabor. This result of the revenue function affirms the decreasing return to scale of the production technology in Nimba County. The result implies that improper use of farming tools especially by male laborers has a desperate negative effect on the level of revenue from the cassava farm. This could be caused by the motive of cassava cultivation in Nimba for food, or due to the low adoption of extension services (Lah *et al.*, 2018).

Table 4.8: Nimba Revenue function and Determinants of Allocative inefficiency

Variables	Coefficient	Std. Err.	Z-value
Revenue function: lnRevenue			
Constant	7.34***	1.83	4.01
Log Cassava farmland	-1.34*	0.73	-1.84
Log Stem-Hoe	-0.43*	0.23	-1.88

Log Machete-Male Labor	-0.32*	0.18	-1.78
Log Hoe-Male Labor	0.31*	0.18	1.71
Log Male-Female Labor	- 0.19**	0.09	-2.04
Log Average output price	0.76***	0.10	7.41
Inefficiency model: Output-oriented allocative inefficiency (-μ_b)			
Constant	5.73***	1.24	4.62
Age	0.01	0.01	1.57
Level of Formal Education	-0.19**	0.85	-2.21
Marital Status (1=Not Single)	0.03	0.07	0.50
Cassava Farming experience	-0.03***	0.01	-3.21
Group Membership (1=Yes)	0.43***	0.15	2.90
Access to Extension (1=yes)	-0.51*	0.28	-1.85
Farm to Market distance	-0.01	0.01	-1.03
Main income (1=farm activity)	-0.70**	0.33	-2.14
Log Average Labor wage	-0.55***	0.20	-2.84
Sigma_μ_b	0.62***	0.13	4.75
Sigma_v	0.39***	0.14	2.81
Lambda	1.61***	0.25	6.27

*, **, *** are significance level at 0.1, 0.05 and 0.01

Source: Author's Computation from Data, 2019

Significant factors influencing output-oriented allocative efficiency are the years spent in formal school, cassava farming experience, group membership, access to extension, farm income, and ln(average)wage of labor. From these variables, farm group membership has a negative effect on allocative efficiency. The other variables of the level of formal education, cassava farming experience, access to extension, and ln(average_wage) are positive determinants of allocative efficiency for cassava production in Nimba county .

At the 10% level of statistical significance, the allocative efficiency of farmers in Nimba increases by 0.19 for an additional completed level of formal education. Education enlightens the farmer to knowledge to comprehend and enhances the ability of the farmer to make "timely and better" decisions. Farmers with high formal education have more opportunities to participate in subsidy, farming training, access credits, inputs, and better output prices. The positive result of formal education is similar to the studies of Lema, (2013) and Nginyangi, (2011); and it is contrasting to the study of Mutoko *et al.*, (2015) whereas farmer obtaining higher education tended to abandon farming activities for non-farm jobs.

An increase in the average wage of labor in the cassava production, at the 1% significance level, will increases the allocative efficiency by 0.55 for farmers in Nimba County. This implies that an increase in the average wage attracts energetic laborers to be hired for farm work. The quality of the labor contracted performs the task is within the stipulated time, especially during the land preparation and planting. Yet, because the wages for each stage of production are synchronized into this average wage, implicit savings can be realized from farm work for which higher wages should have been applied. Hence, the ability to farm properly, and make minimum savings from the stipulated average wage, increase farm revenue from the level of the average wage on future labor contracts. The result is contrasted to a similar study by Berhan, (2015), where the input-oriented allocative efficiency increased with an increase in the wages of onion labor in Ethiopia.

The group membership at 1% statistical significance reduces allocative efficiency by 0.43; but, cassava farming experience at the 1% significant level increases allocative efficiency by 0.03; access to extension contact is significant at 10% and exhibits positive effects of 0.5 on the on the allocative efficiency for an additional extension contact accessed. This positive effect result of extension contacts on allocative efficiency is similar to a study on the efficiency of potatoes farmers (Muzungu, 2011),

4.3 Economic Efficiency Scores of Cassava Production

Economic efficiency was measured based on the output-oriented procedure to maximize output and increase revenue while holding available inputs constant (Coelli *et al.*, 2005). Following the estimations of the production and revenue functions to identify determinants of the technical and allocative inefficiencies for farmers, the two stochastic frontier models, for each of the regions, were predicted to estimate the efficiency scores (technical and allocative) for farmers in Bomi and Nimba counties respectively, and the economic efficiency.

4.3.1 Bomi County

The mean revenue efficiency indices for farmers in Bomi is 40.6 percent; with a minimum index at 1.14 percent and the maximum at 80.68 percent. These results are different to Saysay *et al.*, (2018) study on profit and technical efficiency of rice farmers in central Liberia where mean profit efficiency was found to be 67%; and Oladeebo & Oluwaranti, (2012) mean profit efficiency of 79% in accessing profit efficiency of cassava farmer in southwestern Nigeria. This indicates that there is a potential of 59.4% for farmers in Bomi to become revenue efficient using the existing level of inputs. The average technical and allocative efficiency scores for farmers in Bomi are 63.4 and 57.37 percent respectively.

Comparing the categories of the technical, allocative, and revenue efficiencies among Bomi farmers, there is a trend. In Figure 4.4, the efficiency levels are classed into categories; the lowest efficiency category ranges from 0-19%, and the highest efficiency category runs from 80-99%.

Table 4.9: Summary of Efficiency Scores for farmers in Bomi and Nimba Counties

	Bomi County (n=87)			Nimba County (n=216)		
Category	TE Percent	AE Percent	RE Percent	TE Percent	AE Percent	RE Percent
0-19%	10.34	5.75	26.44	37.5	31.48	73.61
20-39%	11.49	20.69	19.54	31.02	38.43	18.52
40-59%	12.64	21.84	22.99	19.91	21.3	6.02
60-79%	25.29	36.78	29.89	10.65	8.33	1.85
80-99%	40.23	14.94	1.15	0.93	0.46	0.00
Mean	0.6342	0.5737	0.4059	0.3166	0.3107	0.1349

Std. Dev.	0.2585	0.2123	0.2466	0.2062	0.1818	0.1542
Min	0.0750	0.1171	0.0114	0.0291	0.0449	0.0014
Max	0.9418	0.8883	0.8068	0.9832	0.8062	0.7718

Source: Author's Computation from Data, 2019

Key: TE = Technical Efficiency AE = Allocative Efficiency RE = Revenue Efficiency

The technical efficiency scores of cassava farmers in Bomi county increases alongside the pattern of the efficiency categories from the lowest to the highest category. Most of the farmers in Bomi have technical efficiency scores in the category of 80-99%; but this efficiency category also has the smallest group of revenue efficient cassava farmers (amounting to just one cassava farmers). As with the scattered dividend of cassava farmer's technical efficiency within the efficiency categories, the revenue efficiencies are also spread. Thirty percent of cassava farmers' revenue efficiency fall within the efficiency category of 60-79%; followed by twenty-six percent of the farmers' revenue efficiency in the category of 0-19%, and twenty-three percent of the farmers' revenue efficiency within 40-59%.

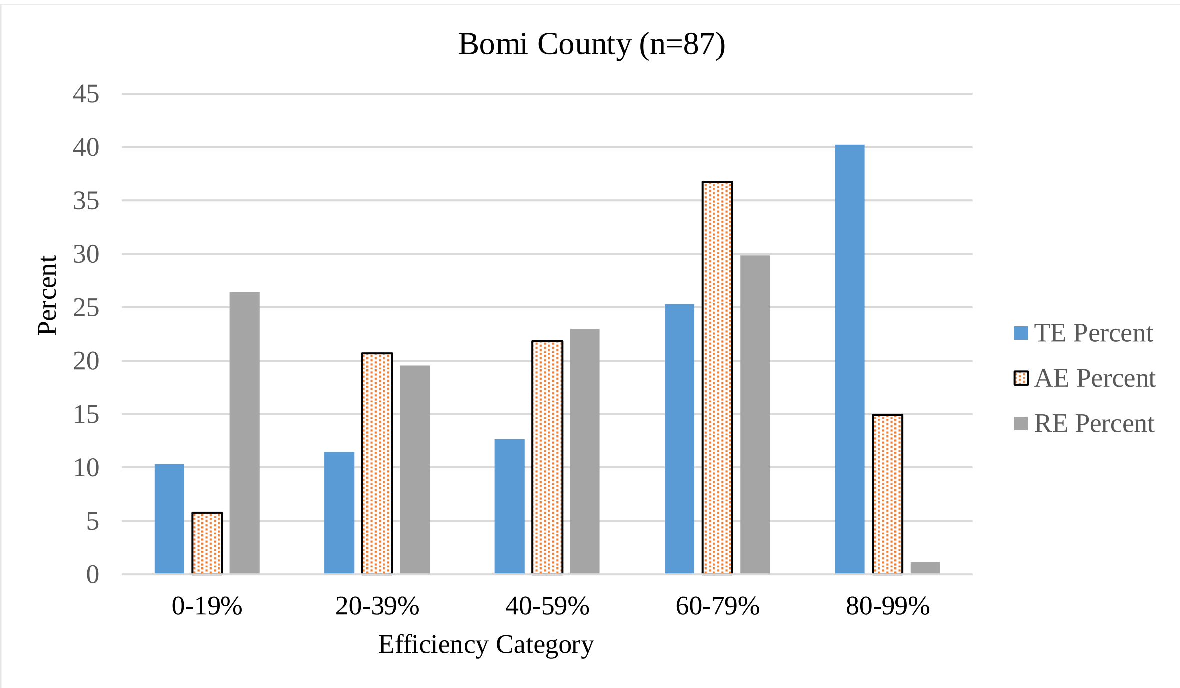

Figure 4.4: Categorization of Efficiency Scores for Farmers in Nimba

4.3.2 Nimba County

The average revenue efficiency among farmers in Nimba is 13.49 percent; ranging from 0.14 to 77.48 percent. This indicates that there is a high revenue-generating capacity of 86.5 percent for farmers in Nimba to become economically efficient from the enhanced utilization of the available resources and output price. This result differs from Adeyemo *et al.*, (2010) result of 89.4% as the mean economic efficiency of small-scale cassava farmers in Nigeria. The mean technical and allocative efficiency of cassava farmers in Nimba County are 0.3166 and 0.3107 respectively.

Reviewing the efficiency scores of cassava farmers to the efficiency categories in Figure 4.5, there is a reverse flow of the farmers technical efficiency scores as the efficiency category move from the lowest to the highest class. Reviewing the allocative efficiency of cassava farmers in Nimba, seventy percent of all farmers have allocative efficiency score below 39%; twenty one percent of the farmers have allocative efficiency within 40-59%, and less than ten percent of the cassava farmers have allocative efficiency between 60-70%. Almost seventy-five percent of the farmers have revenue efficiency scores within the category of 10-19 %; nineteen percent have revenue efficiency score within 20-39% and less than seven percent of the cassava famers have revenue efficiency within 40-59%. No cassava farmer in Nimba has a revenue efficiency score within 80-90%. This indicates that many of the farmers are inconsiderate to the input prices in the allocation of input use. This situation is aligned to the motive of cultivating cassava mainly for sustenance purpose, rather than for farm income.

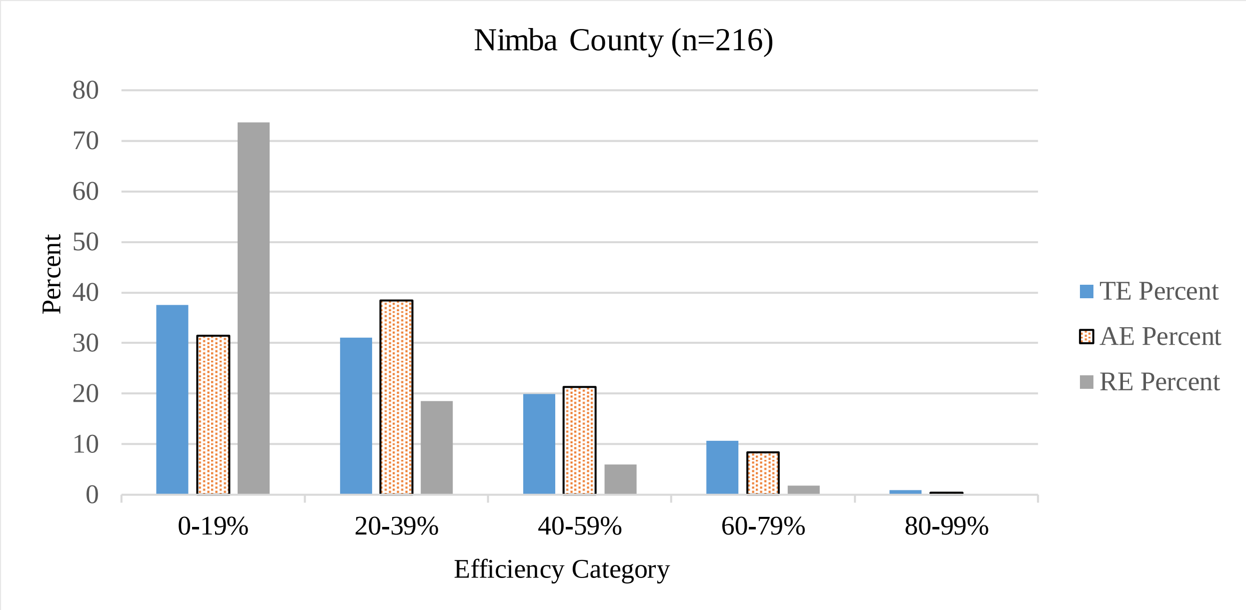

Figure 4.5: Categorization of Efficiency Scores for Farmers in Nimba

4.4 Meta-Frontier Analysis of Cassava Production Efficiency

The estimates from the production frontier of the Bomi and Nimba datasets were pooled to assess the level of "within groups" and "between groups" efficiencies of farmers in the cassava subsector. To adjust for a possible bias of the meta-frontier estimates, the quasi-likelihood estimation (also called sandwich estimation) was used to correct for possible bias in the standard errors. The quasi-likelihood estimation procedure adjusts the standard error, not the estimates, to provide a robust confidence interval for the estimates (Carroll *et al.*, 1998; White, 1982).

Table 4.10: Estimates of Meta-Frontier and determinant of Environmental inefficiency

Variable	Coefficient	Robust Std. Err.	Z-value
Metafrontier dependent variable: Log of Cassava output estimates			
Constant	-0.0020	0.05	-0.04
Log of Cassava farm size estimates	1.0024***	0.02	43.96
Log of Stem Estimates	0.9626***	0.36	2.69
Log of Machete Estimates	1.0002***	0.00	277.3
Log of Hoe Estimates	1.0006***	0.01	181.96

Log of Male Labor estimates	0.9993***	0.01	97.89
Log of Female Labor Estimates	0.9991***	0.01	84.6
Log of Cassava farm size square	1.0011***	0.00	419.96
Log of Stem Estimates square	0.9920***	0.08	12.96
Log of Machete Estimates square	1.0101***	0.10	10.52
Log of Hoe Estimates square	1.0010***	0.01	93.81
Log of Male Labor estimates square	0.9938***	0.07	14.55
Log of Female Labor Estimates square	0.9908***	0.08	12.15
Log of farmland-stem Estimates	1.0029***	0.03	33.95
Log of farmland-machete Estimates	0.9966***	0.03	39.07
Log of farmland-hoe Estimates	1.0006***	0.01	116.24
Log of farmland-male labor estimates	1.0003***	0.00	240.43
Log of farmland-female labor estimates	1.0016***	0.02	63.61
Log of Stem-Machete Estimates	0.9990***	0.01	118.24
Log of Stem-Hoe Estimates	1.0001***	0.00	614.6
Log of Stem-Male Labor Estimates	0.9836***	0.16	5.99
Log of Stem-Female Labor Estimates	1.0102***	0.09	10.83
Log of Machete-Hoe Estimates	0.9955***	0.05	18.37
Log of Machete-male labor Estimates	0.9990***	0.01	75.84
Log of Machete-female labor Estimates	0.9992***	0.01	112.53
Log of Hoe-Male Labor Estimates	1.0012***	0.01	104.4
Log of Hoe-Female Labor Estimates	1.0000***	0.00	356.15
Log of Male Labor – Female Labor Est.	0.9987***	0.01	67.2
Inefficiency dependent Variable: - MU_{b1} (Environmental inefficiency)			
Constant	-1.13	1.34	-0.84
Gender (1=female)	-1.91***	0.43	-4.44
Access to agriculture credits (1= yes)	-2.40***	0.73	-3.3
Sigma_u	0.26	0.60	0.43
Sigma_v	0.01	0.07	0.21
Lambda	18.79***	0.53	35.28

*, **, *** are significance level at 0.1, 0.05 and 0.01

Source: Author's Computation from Data, 2019

In Table 4.10, the lambda value of 18.79 is significant at 1% and indicates that a larger deviation of the stochastic meta-frontier errors is explained by the technology gap ratio (TGR) of the composite error. This means that the fitted model has a large standard variation caused by the environmental factors within the cassava subsector. Hence, the stochastic meta-frontier model is adequately fitted to analyze the environmental factors of all frontiers within the cassava subsector.

Gender and access to agricultural credits are the meaningful environmental variables affecting the performance of cassava farmers in all the groups. At the 1% significance level, an additional female farmer has an increasing magnitude of 1.91 toward the technical efficiency of the subsector; and at the 1% significance level, increasing the access of an additional farmers to credits has a positive effect of 2.4 on meta-technical efficiency of the subsector. This result is consistent to the result Lema, (2013) that access to credits increases the efficiency of conventional farming in Tanzania.

Table 4.11 provides summary statistics of the stochastic technical efficiency of the regions (TE), the technical gap ratio (TGR), and the meta-frontier technical efficiency (MTE) which measures a firm's efficiency toward the meta-production frontier. The mean technical efficiency of farmers in Bomi and Nimba farmers is 0.6342 and 0.3166 respectively; while the mean technical efficiency for the pooled data is 0.4078. Therefore, farmers in Bomi have output-increasing potential of 37.58%; and farmers in Nimba have 68.34% to increase cassava output given the same input levels of inputs in each of the regions. The mean pooled technical efficiency of 0.4078 is the justifiable estimate to unbiasedly explain the joint efficiency levels of the cassava sector involving farmers in Bomi and Nimba. The statistical differences of the means and heterogeneity of the production frontiers for the regions will induce biasedness if datasets are pooled and analyzed without an enveloping metafrontier is necessary to compare the joint efficiency of different technologies (Battese & Rao, 2002).

The technical gap ratio (TRG) for Bomi, Nimba and the pooled datasets are 0.9930, 0.9926 and 0.9927 respectively. The TGR indices are used to compare the technical efficiency of firms to validate the level of overall resources available and factors influencing the environment of group frontiers (Huang, Huang, & Liu, 2014). The result showed that the TGR ratio is high and steady for cassava production across Bomi and Nimba counties. The result is consistent with several studies in agriculture (Alem *et al.*, 2017a; Chen & Song, 2008; Majiwa & Mugodo, 2018), energy (Lin & Du, 2013), and industrial firms productivity (Tunca et al., 2013) in which at the least the TGRs are higher was than 90%. However, this TGR results of this study are higher than studies of Boshrabadi *et al.*, (2006) on wheat, and Gwebu & Matthews, (2018) on tomatoes productions.

Table 4.11: Meta-frontier Efficiency Statistics

Variable	Mean	Std. Dev.	Min	Max
Bomi (n=87)				
TE	0.6342	0.2585	0.0750	0.9418
TGR	0.9930	0.0008	0.9911	0.9943
MTE	0.6297	0.2566	0.0744	0.9352
Nimba (n=216)				
TE	0.3166	0.2062	0.0291	0.9832
TGR	0.9926	0.0009	0.9908	0.9942
MTE	0.3143	0.2048	0.0289	0.9761
Pooled (n=303)				
TE	0.4078	0.2646	0.0291	0.9832
TGR	0.9927	0.0009	0.9908	0.9943
MTE	0.4048	0.2627	0.0289	0.9761

Source: Author's Computation from Data, 2019

Key: TE = Technical Efficiency TGR = Technical Gap Ratio MTE = Meta-TE

The TGR is predicted from the stochastic meta-production frontier, in similar manner as group technical efficiency scores (Huang *et al.,* 2014; Jondrow *et al.,* 1982). The result of the TGR indicates that available inputs are nearly at full capacity. With the TGR of the pool data at 99.27%, only 0.73% of cassava production inputs are unavailable in the cassava sub-sector. The structure of labor markets, extremely low use of fertilizer, pesticides and the different varieties of stem/planting materials are contributing reasons for the level of gap.

The average meta-frontier technical efficiency (MTE) score for farmers in Bomi, Nimba and with the pool, data are 0.6297, 0.3143, and 0.4048. As a measure of group efficiency to the meta-frontier, it is a better statistic for comparing the group's efficiencies. A firm's MTE is affected by its group's TGR; i.e the higher the TGRs, the lower the adjustment from TE to

MTE levels, and vice versa. The result shows that cassava farmers in Bomi County are technically twice efficient as cassava farmers in Nimba County. Given the available production resources in the sector, there are potentials for farmers in Bomi and Nimba to increase cassava outputs by 0.3713 and 0.6857 respectively. The mean MTE for all cassava farmers in the cassava subsector is 0.4048; this indicates that there is a potential of 59.52% for all farmers within the cassava subsector to technically optimize the estimated meta-frontier from the use of the available production inputs.

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CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

The goal of the study was to analyze the economic efficiency of cassava production in Bomi and Nimba Counties. Almost eighty percent of all agriculture households cultivate the crop. Yet, there is an aggregate low supply to meet the local demand despite the government's selection of cassava as the agriculture crop to provide food subsidy, lead an agriculture-led growth the economic recovery. Also, there are knowledge gaps about the levels of efficiency to support key policies that seek to boost the cassava subsector. A multi-stage sampling procedure was used to select Bomi and Nimba as the study areas and participants. From three hundred three participants interviewed, data from cassava farms, farmer's demographics, socio-economic and institutional factors were used to estimate stochastic frontier models.

In Bomi, the technical, allocative and economic efficiency for cassava farmers are 63.4%, 57.4%, and 40.6% respectively; and those for cassava farmers in Nimba are 31.7%, 31.1%, and 13.5% respectively. Farmer's age and farming group membership are reducing factors to the economic efficiency of cassava production in Bomi and Nimba. However, cassava farming experience and accessing extension contacts are increasing factors of the economic efficiency of cassava production in Bomi and Nimba counties.

The cassava subsector in Liberia, containing all farmers in Bomi and Nimba, is technically efficient at 40.48%. Gender, in the favor of female farmers, and access to credits are the increasing environmental factors to achieve technical efficiency of cassava production in the subsector.

5.2 Conclusion

The study determined the economic efficiencies for cassava farmers in Bomi and Nimba counties, and the meta-technical efficiency for all farmers of the subsector to specifically test the hypotheses that: (a) cassava farmers in Bomi and Nimba counties *were not* economically efficient, and (b) cassava farms in Bomi and Nimba counties *were not* fully utilizing the capacity of available inputs in the cassava sub-sector.

Based on the determined economic efficiencies scores of 40.6 percent and 13.5 percent for cassava farmers in Bomi and Nimba counties respectively, the study "fail to reject" the null hypothesis and concludes that farmers in Bomi and Nimba counties are not economically efficiency in cassava production. There are potentials of 59.4% and 87.5% for farmers in Bomi and Nimba to respectively improve their economic efficiencies.

Also, the determined meta-technical efficiency score of 40.48 percent for cassava farmers in the cassava subsector indicates that the available production resources are currently been underutilized. Hence, the study "fail to reject" the second null hypothesis and concludes that farmers in the subsector are not fully utilizing the available production resources within the subsector. There is a potential of 59.52% to improve the technical use of the available production resources.

5.3 Recommendation

5.3.1 Recommendation for Policy and Decision Makers

More women participation in the cassava sub-sector, employment of younger farmers (and younger people), and the provision of agriculture credits to cassava farmers will increase the technical efficiency of cassava farmers to produce optimally. Implementation of relevant policies and laws that support women's access to and control of production resources should be encouraged to improve the technical efficiency of cassava production in Liberia. Strong publicity and awareness for young people and younger farmers to see the cassava sector as a credible business opportunity to provide food and generate income is a good policy intervention. Going further, targeting such awareness through the formal primary and secondary school system and establishing public demonstration plots for students to test cassava stem varieties and practices will enlighten farmers (and would be farmers) and boost the production efficiency of cassava.

Farming groups, not farming corporative, are irregularly existent during farming seasons. Farm groups have lower membership and are the basic units of corporative, but their shorter activeness and lifespans limits them to access extension services and long term social benefits. Interventions to organize cassava farm groups with incentives for longer staying groups can be a pivotal point to easily reach the integral units of farmers with extension services, and microfinance products including microcredits and social entrepreneurship skills since their membership are more manageable than cooperatives.

Deplorable and challenging roads, especially in Nimba County, is a contributing factor to the low economic efficiency cassava farmers even when they are producing high quantity. An intervention to connect viable farm-to-market road, and subsidies to connect rural markets with international markets, through exports of cassava output and products especially to emerging Asian markets, are worthy policy considerations to improve production efficiency and boost the cassava sector.

5.3.2 Recommendations for cassava farmers and farm managers

With the current use of farm resources, farm managers and farmers in Bomi are encouraged to continue using the available production resources in the same manner as they were doing. However, there is a need to check the ratio of farm size to the bundle of stem they plant to optimize production efficiency. Planting more than a required stem bundles to the mean farm size could increase output but reduce the technical efficiency of their cassava production. Farmers in Nimba however, are cautioned to revisit their use of production resources because they are experiencing decreasing returns to scale on their production function. For example, farmers should consider diversifying their farmland by planting other crops on a portion of the previous cassava farm; because at the current level, increasing farm size will reduces the expected output from a mean farm.

Employing specific labor efforts, either from male or female, to complete a particular tasks is important to increase efficiency and stimulate production. In Bomi, employ men efforts mainly to prepare the land, and women to weed the farms. However in Nimba, employ more female efforts for farmland preparation, planting the stems, and weeding the cassava farm because they are more effective than men.

Regardless of the region, the task to be done or the phase of production, farm managers and farmers are encourage to employ young and energetic labor to perform labor contracts. As a rule of thumb, employ laborers below 35 years old because they have better agility to contribute to the efficiency of the cassava production.

Farmers in both Bomi and Nimba need to seek help from extension service providers. Extensions agents provide basic and farmer's specific information on the necessary tools to use, the variety of cassava stem to plant, and advices along the production chain. For a start, farmers in Nimba should seek advice from extension officers and cassava farmers from Bomi about the best cassava production techniques to improve their efficiency levels.

5.4 Areas for Further Research

The following areas are worthy of future research considerations:

1. There are three concentrated cassava regions in Liberia with farmers having probably different motivations to cultivate cassava. Supported by the current study, farmers in Bomi are motivated to plant cassava for income, while farmers in Nimba do so mainly for sustenance purposes. A future study can expand the scope to all three cassava clusters, and consider the relationship of cassava farmers' motivation to production efficiency;

2. The current study was done on cross-sectional data collected on a single visit. Information collected from the farmer was based on the memory of inputs used, prices, and production activities. A future study can consider multiple visits to collect actual cross-sectional data during the actual production activities (of land preparation, planting and weeding), or use a time series approach to measure cassava production efficiency for many years;
3. The current study analyzed observations from 87 farmers in Bomi and 216 farmers in Nimba County respectively. When estimating the regional disaggregated datasets, gender was superfluous. Rather, gender was significant in the meta-frontier analyses of the pooled data. The rejection of gender in the separate models could be due to the number of separate observations from the counties. Increase the sample size in a future study to assess the effect of the farmer's gender on the economic efficiency of cassava production in each of the counties is a good research opportunity;
4. Age-productivity follows a pattern of entry, growth, and exit as a farmer gets older. This is important for planning and implementing farming support services such as farming insurances and customizing extension packages. The current study posits that cassava farmers are experiencing declining age productivity to cassava efficiency, but did not explicit identify the age-productivity stages. Hence, this is an opportunity for a future study to establish the stages of age-productivity for cassava farmers in Liberia.

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APPENDIX I: DIAGNOSTIC TESTS

Table A-1: Shapiro Francia Test of Variables (n=303)

Variable	W'	z	Prob>z
Cassava Output	0.8049	8.774	0.000
Stem Quantity	0.8242	8.529	0.000
Machete Quantity	0.7003	9.782	0.000
Hoe Quantity	0.6629	10.058	0.000
Labor_land Preparation	0.5728	10.615	0.000
Labor_Planting	0.6213	10.331	0.000
Labor_Weeding	0.696	9.816	0.000
Age	0.9658	4.688	0.000
Gender	0.9987	-2.994	0.999
Experience	0.8524	8.118	0.000
Marital Status	0.9122	6.900	0.000
Level of Education	0.9948	0.278	0.390
Non-farm Income	0.6231	10.321	0.000
Household size	0.9108	6.936	0.000
Farm group membership	0.9422	5.918	0.000
Access to credits	0.9932	0.883	0.189
Access to Extension	0.9909	1.566	0.059
Farm to market distance	0.7388	9.460	0.000

Source: Author Author's Computation from Data, 2019

Table A-2: Chi2 ($\chi 2$) and Cramer's V stats (n=303)

Row Variable	Column Variable	Pearson Chi^2	Prob.	Cramer's V
Cassava Output	Gender	54.5096	0.708	0.4241
Cassava Output	Age group	382.2430	0.038	0.4570
Cassava Output	Level of Education	270.5483	0.996	0.3845
Cassava Output	Yrs.in sch. (group)	100.1852	0.987	0.3700
Cassava Output	Marital Status	352.9594	0.240	0.4392
Cassava Output	Source of Income	101.4002	0.984	0.3722
Cassava Output	Access to Extension	84.3665	1.000	0.3395
Cassava Output	Access to credits	87.6946	0.999	0.3461

Row Variable	Column Variable	Pearson Chi^2	Prob.	Cramer's V
Cassava Output	Group Membership	137.8153	0.393	0.4339
Gender	Age group	3.6053	0.608	0.0993
Gender	Level of Education	42.1950	0.000	0.3395
Gender	Marital Status	21.9585	0.000	0.2449
Gender	Source of Income	4.7926	0.091	0.1144
Gender	Access to Extension	0.7043	0.703	0.0439
Gender	Access to credits	1.0026	0.606	0.0523
Gender	Group Membership	13.0723	0.001	0.1890
Age group	Level of Education	41.5761	0.020	0.1507
Age group	Marital Status	18.1424	0.003	0.2226
Age group	Source of Income	10.8154	0.372	0.1216
Age group	Access to Extension	4.2058	0.938	0.0758
Age group	Access to credits	10.6775	0.383	0.1208
Age group	Group Membership	10.8586	0.369	0.1218
Level of Education	Yrs.in sch. (group)	172.1670	0.000	0.4850
Level of Education	Marital Status	15.5615	0.008	0.2062
Level of Education	Source of Income	14.4856	0.152	0.1407
Level of Education	Access to Extension	11.8331	0.296	0.1271
Level of Education	Access to credits	8.8594	0.545	0.1100
Level of Education	Group Membership	18.3581	0.049	0.1584
Yrs.in sch. (group)	Marital Status	2.0305	0.362	0.0745
Yrs.in sch. (group)	Source of Income	0.4809	0.975	0.0256
Yrs.in sch. (group)	Access to Extension	2.7336	0.603	0.0611
Yrs.in sch. (group)	Access to credits	3.0110	0.556	0.0641
Yrs.in sch. (group)	Group Membership	8.5333	0.074	0.1080
Marital Status	Source of Income	0.4086	0.815	0.0334
Marital Status	Access to Extension	2.0345	0.362	0.0746
Marital Status	Access to credits	0.8607	0.650	0.0485
Marital Status	Group Membership	0.7085	0.702	0.0440
Source of Income	Access to Extension	13.1996	0.010	0.1343
Source of Income	Access to credits	4.0081	0.405	0.0740
Source of Income	Group Membership	19.8308	0.001	0.1646
Access to extens.	Access to credits	368.9409	0.000	0.7099
Access to extens.	Group Membership	1.3467	0.853	0.0429
Access to credits	Group Membership	0.6907	0.952	0.0307

Source: Author Data Analysis output, 2019

Table A-3: The Variance Inflator Factor test

Variable	VIF	1/VIF
Level of Education	4.33	0.23
Year in School	4.29	0.23
Region	1.98	0.51
Machete quantity	1.69	0.59
Planting Labor quantity	1.68	0.59
Experience	1.65	0.60
Hoe quantity	1.65	0.61
Age of farmer	1.60	0.63
Weeding labor quantity	1.51	0.66
Access to extension	1.51	0.66
Stem quantity	1.46	0.69
Household Size	1.37	0.73
Distance to farm market	1.32	0.76
Sex of the farmer	1.31	0.77
Land prep. labor quantity	1.22	0.82
Marital status	1.18	0.85
Access to credits	1.13	0.89
Non farm income	1.09	0.91
Group membership	1.08	0.92
Mean VIF	1.74	

Table A-4: Spearman Rank Correlation Matrix (n=303)

	Cassava Output	Stem quantity	machete quantity	Hoe quantity	Land prep Labor	Planting labor	weeding Labor	Age	Gender	Farming Experience
Cassava output	1									
Stem quantity	0.4756	1								
machete quantity	0.1434	0.3701	1							
Hoe quantity	0.1097	0.4128	0.5810	1						
Land prep Labor	0.2996	0.3578	0.2457	0.3051	1					
Planting labor	0.1730	0.2289	0.1491	0.2735	0.5457	1				
weeding Labor	0.2281	0.2720	0.1711	0.2509	0.4310	0.5863	1			
Age	-0.0814	0.0313	0.1057	0.1047	0.0204	0.0909	0.0450	1		
Gender	0.1190	0.0306	-0.0100	0.0044	0.0315	0.0592	0.1247	0.0517	1	
Farming Experience	0.2439	0.0962	0.0440	-0.0093	0.1699	0.1287	0.1013	0.3985	0.0741	1
Marital Status	-0.1352	-0.0650	-0.0125	-0.0832	-0.0834	-0.0336	-0.0526	0.0617	-0.2809	0.0239
Level of Education	0.1488	0.0601	-0.0682	-0.0563	0.0433	0.018	0.1054	-0.2100	0.2981	-0.2368
Years in School	0.1924	0.0994	-0.0447	-0.0253	0.1019	0.0642	0.1367	-0.1458	0.3442	-0.2022
Source of Income	0.0686	0.0966	0.0757	0.1092	0.0733	0.0523	0.1049	0.0361	0.0586	0.0322
Household size	0.0066	0.1463	0.3069	0.1867	0.0847	0.1407	0.0823	0.3376	-0.0727	0.1456
Group membership	-0.1352	-0.1240	-0.0715	-0.0628	0.051	-0.0223	-0.0599	-0.0098	0.1038	-0.0699
Access to credits	0.1066	0.0296	-0.0423	-0.0794	0.0523	0.0270	0.0111	-0.0841	0.0238	0.0698
Access to extension	-0.0871	0.0635	-0.1444	-0.0983	-0.1036	-0.0489	-0.0074	0.0071	0.0190	0.2330
Farm-market road	0.1795	0.2806	0.1837	0.1432	0.2198	0.0949	0.0841	-0.0261	-0.1860	0.1351

Correlation diagnostic test on variables: Spearman Rank Correlation Matrix continue…

	Marital Status	Level of Education	Years in Formal School	Source of Income	Household size	Group membership	Access to agriculture credits	Access to extension	Farm-market road
Marital Status	1								
Level of Education	-0.1633	1							
Years in School	-0.1505	0.8909	1						
Source of Income	-0.0353	0.0730	0.0644	1					
Household size	-0.0669	-0.1245	-0.1395	0.0237	1				
Group membership	-0.0410	0.1243	0.0959	0.0481	-0.0983	1			
Access to credits	-0.0004	0.0983	0.0477	0.0944	-0.1180	0.0794	1		
Access to extension	0.1046	-0.1096	-0.0899	-0.0032	-0.2255	0.0967	0.0931	1	
Farm-market road	0.0044	-0.0755	-0.1102	0.0992	0.2102	-0.1459	0.0892	-0.0960	1

Source: Author Data Analysis output, 2019

The result from the Spearman matrix also showed that the pair of "Years of schooling" and "Level of Educational" had stronger association of 89 percent. Other stronger association were found between the association of the factors of production (stem, machete, hoes and labor).

APPENDIX II: LETTER FROM DEPT. AGRICULTURAL ECON, UON (copy)

UNIVERSITY OF NAIROBI
COLLEGE OF AGRICULTURE AND VETERINARY SCIENCES

DEPARTMENT OF AGRICULTURAL ECONOMICS

Telephone: +254 20 3592734-6 Ext. 27015, 020 2091967
Direct line +254 20 2091967
Email agecon@uonbi.ac.ke

P.O. Box 29053-00625
Nairobi, Kenya
Kabete Campus

Date: May 3, 2019

TO WHOM IT MAY CONCERN

Dear Sir/Madam,

RE: INTRODUCTORY LETTER FOR MR. KOLLIE B. DOGBA – A56/9511/2017

This is to confirm that the above named is a student, pursuing MSc. degree in Agricultural and Applied Economics in the Department of Agricultural Economics, University of Nairobi.

Mr. Dogba would like to undertake research work in Bomi and Nimba Counties, Liberia from 5th May to 28th June, 2019. This is to enable him complete his Masters project entitled: **"Determining the Economic Efficiency of Cassava Production in Bomi and Nimba Counties, Liberia."**

Any assistance accorded to him will be highly appreciated.

Yours faithfully,

PROF. JOHN MBURU
CHAIRMAN,
DEPARTMENT OF AGRICULTURAL ECONOMICS

UNIVERSITY OF NAIROBI FACULTY OF AGRICULTURE TEL: 254-020 631340, 631354 EXT 27032 FAX 254-020 631015 P.O. Box 29053, NAIROBI, KENYA DEPARTMENT OF AGRICULTURAL ECONOMICS

APPENDIX III: LETTER FROM LOCAL COUNTY ADMINISTRATION, RL (copy)

REPUBLIC OF LIBERIA
MINISTRY OF INTERNAL AFFAIRS
Nimba County

Office of the County Inspector

Memorandum

FROM	:	Reginald Mehn County Inspector, Nimba County
TO	: : :	All Statutory District Superintendents Administrative District/County/Township Commissioners City Mayors/Paramount/Clan/Zone/Quarter Chiefs, Nimba County, Liberia
DATE	:	**May 21, 2019**
SUBJ.	:	**OFFICIAL INTRODUCTION**

We have the honour to present our compliments and write to officially introduce to you the bearer of this document, **Mr. Kollie B. Dogba – A56/9511/2017,** a Liberian and student of the **University of Nairobi, Kenya** pursuing MSc. Degree in Agricultural and Applied Economics in the Department of Agricultural Economics of said University.

Mr. Dogba is undertaking research work in Bomi and Nimba Counties from May 5 – June 28, 2019 to enable him complete his Masters project entitled **"Determining the Economic Efficiency of Cassava Production"** in Bomi and Nimba Counties.

In view of the above, we are requesting all local and municipal authorities of Nimba County to accord him with maximum security protection as well as needed assistance he may stand in need during his research work. Please see copy of attached document for your information and cooperation.

Best regards,

APPENDIX IV: SAMPLE SET OF SURVEY QUESTIONNAIRES

2019 CMAAE/UON CASSAVA SURVEY IN LIBERIA

Hello Sir/Madam. My name is ------------.

Please allow me to ask you few questions about your cassava farm. The reason is to get information on cassava production from last cassava farming season in Bomi and Nimba counties. The information we get will be used for study purpose only.

Enumerator Identification

Check your name to begin the survey

Farm Location Data

1. In Which county do you have your cassava farm?
2. In which administrative district is the farm located?
2. In which administrative district is the farm located?
3. What is the name of the community you live in?

Demographic and Social Capital data

4. Who is the head of the family?
5. How old is the head of the family in years?
6. What is your level of formal education?

Please specify the other level of formal education

7. How many years you spend in formal school?
8. Are you...? Read out the household marital status to the respondent
9. How many members do you have in your family?
10. How many household member working to support the family?
11. From which activity you get your main income as the family head?

What is the the main crop from which you get your main income.

What is the main activity/job from which you get your main income.

12. How many years you have been farming cassava?
13. How many farming group you are a member of? Hint: It does not mean membership in a cooperative

Please specify the number of "groups"

14. How can you describe the farming group you are a member of? Read out the options to the respondent

Production farm group Details:

How many time the group met in a month?

What is the main production benefit you received from this farming group? Read options to respondent

How many time did you receive this benefit over the last 12 months?

Processing farm group details:

How many time the group met in the month?

What is the main processing benefit you received from this farming group? Read options to respondent

How many time did you received this processing benefit over the last 12 months?

Marketing farm group Details:

How many time the group met in a month?

What is the main marketing benefit you received from this farming group? Read options to respondent

How many time can you remember receiving marketing benefits over the last 12 months?

Financial Group Details:
How many time the group met in a month?
What is the main financial benefit you attain from this farming group
How many time can you remember receiving credits benefits over the last 12 months?

Other Group Details:
Specify "Other" Group type
How many time the group met in a month?
What kind of benefit you get from this other type of farming group?
How many times did you receive this benefits during the last 12 months?

Cassava data (Farm Data)
In the next section, I will be asking you about farm size, land sources and costs
15. How many total acres of land you own / control?
16. Did you get the total Land by...?
Land Inheritance Details:
So, how many inherited acres you own?
How much is an estimate price (in US$) for an acre of the land you inherited?

Land Bought Details:
Okay, how many acres were bought?
How much you pay (in US$) for an acre of the land bought?

Land Tenancy Details:
From the total land, how many acres were leased/rented?
How much was the rent paid (estimate in US$) for an acre?

Other Land Source Details:
Please Specify "Other source of Land"
From the total land, how many acres are from other source?
Estimated price (in US$) per acres of other source

17. From the last farming season, which planting style did you use to plant cassava?
From last farming season, how many (estimate) acres of land were planted with ONLY Cassava?
From last farming season, how many (estimate) acres of land were planted with mixed crops, including cassava?
From last farming season, how many (estimate) acres were planted with CROPS EXCLUDING CASSAVA ?
18. When you are planting the cassava stems, do you consider "the spaces" between the cassava cuttings?
Great! so how do you measure that "space" between the stems? Read aloud the option to the respondent
Please specify "other" measures in the previous question

What is the planting space-apart between cassava stems?
Width

Length

If not, what main reason relates to why you don't consider the planting space?
19. What is your main reason for planting cassava? Food ( ) Income ( ) Animal Feeds ( )

In the next section, I will be asking questions concerning cassava inputs, outputs, prices and costs related to cassava production mostly concerning last farming season
20. What is the local name for the type of cassava you plant?
Please state the other local names
21. How many bags of cassava you harvested from last farming season?
What is the main kind of bag you measured your cassava in?
22. What was the Price (estimate in LR$) for the bag of Cassava during last farming year?
23. What is the price now (estimate in LR$) for the bag of cassava?
24.On the average, you harvested how many packs of cassava from a single cutting you planted last farming season? Hint: 1 bag (25kg) = 8 packs
25. Please provide information about the following inputs you use to produce cassava…
Cassava Stems / Cuttings:
How many bundles of cuttings did you use?
What is the cost (estimate) for a bundle of cassava stem?
How much money (total estimate) you spent to get all the cassava cuttings?

Fertilizer:
How many kilogram (kg) of fertilizer did you used last farming season?
What is the price for one kilogram of fertilizer?
How much (total amount in LR$) did you spent to get fertilizer last farming season?

Pesticides:
How many quantity (liters) of Pesticides (bug killer) you used?
How much in total did you spent for pesticides for last farming year?

Cutlass / Machete:
How many cutlass did you used on the farm?
How much is the price for one cutlass?
How much did you spent altogether to get the cutlass(es) you used on the farm?

Digging Hoe:
How many digging hoe did you used for farming?
How much is the price for one (1) digging hoe?
How much did you spent altogether to get the digging hoes for the farm?

26. For last farming season, what is the main source from which you got the money to get .... ?

Inputs	Farm Income	Non farm Income	Agriculture Credits	Others	Non Applicable
Cassava Stem					

Fertilizer					
Pesticide					
Machete / Cutlass					
Digging Hoe					

Please specify "Other" Source (If you ticked the Others; otherwise move onward)
Other inputs
Please Specify "Other Input"
How many quantity of this other input did you used?
How much is the price for one of this "other input"?
From which main source you got the money to buy this "other input"?
Please state the non-farm income
How much total money did you spent to get this "other input" for the farm?

27.Please give me information about how people worked and how they were paid during the farming season?
Land Preparation:
For last season, how much did you spend for preparing the land for the cassava farm?
How many persons worked to prepare the land for the cassava farm?
Please tell me how many men and women prepared the land for the cassava farm?
Male
Female
How many working days/weeks did it take to complete the land preparation for the farm?
If you're to pay for somebody preparing the land, how much (in LR$) will you Pay per day?

Planting the Stems:
From last season, how much did you spend for the planting activity?
How many persons planted the cassava farm last farming season?
Please tell me how many men and women planted the cassava cuttings last farming season?
Male
Female
How many working days did it take to completely plant the cassava farm?
How much is the "wage per man-day" (in LRD$) for someone helping you to plant the cassava stem?

Weeding the farm:
How much (estimate) did you spent for the weeding activity?
How many persons weeded the cassava farm last farming season?
Please tell me how many men and women weeded the cassava farm last season?
Male
Female
How many working days did it take to completely weed the cassava farm?
How much is the "wage per man-day" (in LRD$) for someone helping you to weed the cassava farm?

Applying Fertilizer:
How much was spend (total amount) for fertilizer application activity?

How many persons applied the fertilizer to the cassava farm last farming season?
Please tell me how many men and women apply the fertilizer for the cassava farm?
Male
Female
How many working days did it take to completely apply fertilizer to the cassava farm?
How much is the "wage per man-day" (in LRD$) for someone helping you to apply fertilizer to the cassava farm?

Applying Pesticides (Bug killers):
For the pesticide application, how much (total estimate) did you spend?
How many persons applied the pesticide to the cassava farm last season?
Please tell me how many men and women apply the pesticide to the cassava farm?
Male
Female
How many working days did it take to completely apply pesticide to the cassava farm?
How much is the "wage per man-day" (in LRD$) for someone helping you apply pesticide to the cassava stem?

Harvesting:
How many persons worked to harvest the cassava farm?
How many persons harvested the cassava farm?
Please tell me how many men and women harvested the cassava farm last season?
Male
Female
How many working days did it take to completely harvest the cassava farm?
How much is the "wage per man-day" (in LRD$) for someone helping you to harvest the cassava tubers?

28. For last farming season, where did the the people who worked for you come from to … ? for example prepare the land, weed the farm, etc

Activity	**Family**	**Hired**	**Farming group**	**Others**	**Not Applicable**
Prepare the land					
Plant the stem					
Weeding					
Apply Fertilizer					
Apply Pesticide					
Harvest the cassava					

Please state other labor sources (if "others" was ticked; otherwise move onward)

29. For last farming season, where did you get money to pay people who....? For example, Prepare the land, plant the cuttings, weed...

Activity	**Farm Income**	**Non farm Income**	**Agriculture Credits**	**Others**	**Non Applicable**
Prepare the land					

Plant the stem					
Weeding					
Apply Fertilizer					
Apply Pesticide					
Harvest the cassava					

Other activity using Labor:
Please indicate the name of the Other activity
On the cassava farm, how much (in total) was spend for this activity?
How many persons worked on this activity on the cassava farm?
Male
Female
How many working days did it take to completely finish this activity on the cassava farm?
How much is the "wage per man-day" (in LRD$) for someone helping you do this activity on the cassava farm?
Where do you get people from to help you complete this activity on the cassava farm?
Pleas specify the "Other" labor source for this activity
What is the main fund source, you get money from, to pay for this activity?
Pleas specify the "Non-farm income" labor fund source for this activity

In the next section, I will be asking about other information about markets, extension service, credits and other non-farm works

Access to Markets

30. When you walk from your farm, how long it takes you to reach the place where you buy your cassava inputs?

Please input the other time spend

31. how much is the transportation (estimate in LR$) for a person from your farm to this market (where you buy cutlass, hoe, cuttings, etc)?

32. How long it takes you to reach the BIGGEST general market from your farm when you are walking?

33. Please give the name of the biggest public market

34. What is the transportation cost (estimate in LR$) for "the bag" of cassava to this public market?

35. What is the transportation cost (estimate in LR$) for a person from your farm to this big public market?

36. How long it takes you to reach the NEAREST community market from your farm when you are walking?

Please give the other time spend

37. What is the transportation cost (estimate in LR$) for "the bag" of cassava to the nearest community market?

38. What is the transportation cost (estimate in LR$) for a person from your farm to the nearest community market?

39. What is the road made out of. Say from your farm to ...

Destination	**Cottar**	**Gravel**	**Sand**	**Mud**
Input market				
Community market				
Biggest public market				

40. How can you describe the general road conditions from your farms to markets?

Extension Services

41. During last farming season, did you received farming advice, training or support from anywhere else beside the farming groups?

From which Main source you received the extension services? Was it from...

Please specify the other extension service source

What main type of extension service/support you receive from this source?

How many times did you get extension visit/support from this provider in the last 12 months?

Agriculture Credit

42. Did you receive credits for your cassava farm last season?

Select your main source for agriculture credits? Was it from...

Specifically, how was the process like to access the credit for your farm?

Please select two main reasons that made it difficult for you to receive agricultural credits?

1st choice

2nd choice

Non-farm activity

43. As a farmer, what other part-time work you do outside the farm work?

Specify the Non-farm work

how many times you do this non-farm work in a month?

On the overall, how much can you receive (in LRD$) from this work in a month?

44. In last season farming, which farm item you spend most on? For example, was it on Land, Labor, fertilizer, farm tools...

Please state the Other Most expensive farm item

45. Thank You so much. Please, can I take a picture.... Hint: Only one picture can be attached.

- End -