GSJ: Volume 8, Issue 3, March 2020, Online: ISSN 2320-9186
www.globalscientificjournal.com

EXPLORATION OF RICE CULTIVATION AND OPPORTUNITIES IN SIERRA LEONE: USING AN ARMINGTON BASED PARTIAL EQUILIBRIUM MODEL TECHNIQUE

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KeyWords
Rice Sub-sector, Import Penetration, Rice Distribution, Armington Model, Partial quilibrium, Sierra Leone.

ABSTRACT

In this paper, we presents an armington based partial equilibrium mode techniques for exploration of rice cultivation and opportunities in Sierra Leone: The rising import bill of rice and the dependence of Sierra Leone on imported rice coupled with the growing sophistication of the rice consumer for quality rice and the agronomic advantages in rice cultivation initiated this research into Sierra Leone's rice sub-sector. The research question for this study is what opportunities do the current state of Sierra Leone's rice sub-sector offer compared with the rice imports? Therefore, the first objective is to analyze the development of Sierra Leone's rice sub-sector through a trend analysis of production levels, acreage under cultivation, and yield per hectare and rice import penetration ratio from 2000 to 2018. The results show that although rice cultivation in Sierra Leone is increasing at a rate of about 5.8 percent annually between the years 2000 and 2018, Sierra Leone still depends heavily on imported rice. The import penetration ratio in 2011 was about 66 percent. Secondly, the study shows analysis of the rice distribution network and identify the opportunities to shift to rice varieties demanded by consumers thanks to a schema of the rice distribution network. The analysis of the rice distribution network shows that the imported rice channel is more efficient than the local rice channel. The most influential operators in the imported rice channel is the rice importer whiles the rice wholesalers (market women) are the most influential in the local rice channel. There exists some form of oligopolistic system between market women and the rice farmers because the farmers are constrained to sell to the market women due to the lack of greater access to market centers for better competitive prices. Thirdly, the study identified different agricultural and trade policies that could affect production, consumption and imported quantity of rice using a simulation model. A simply Armington based partial equilibrium model of Sierra Leone's rice sub-sector is developed and the simulation results show that the total removal of current taxes on imported rice would lead to 8 and 6 percent decrease in aromatic and non-aromatic rice cultivation respectively. Imports of aromatic and non-aromatic rice would increase by 55 and 63 percent respectively. Overall rice consumption would increase by 21 percent. For a 20 percent increase in land cultivated, rice cultivation will increase by 24 percent and consumption would increase by 9 percent. A 20 percent increase in rice productivity would lead to a 5 percent increase in rice cultivation and 12 percent increase in rice consumption. A 20 percent decrease in world rice prices would lead to a 5 percent decrease in cultivation and 14 percent increase in consumption. For a 20 percent increase in world rice prices, cultivation would increase by 4 percent and consumption will decrease by 9 percent. This research recommends that land expansion and trade liberalization in the short term should be promoted while improving rice farmers' productivity in the short, medium to long term to boost cultivation levels. Also, for accelerated rice production, government policy should be geared towards encouraging large scale farmers to enter the rice sub-sector while government continues to improve the productivity of the smallholder rice farmers. Government should improve infrastructure especially roads to open up rice farming communities to market centers and reduce transactions costs and reduce the oligopolistic system operated by market women.

I. Introduction

1.1 Background Study

Agriculture continues to play an important role in Sierra Leone's economy. In 2016, the sector contributed about 35 percent of gross domestic products (GDP) [1]. The sector employs an estimated 51 percent of the economically active population [2]. Sierra Leone has 13,628,179 ha of agricultural land and 55 percent is under cultivation. Farmers continue to depend largely on rain-fed agriculture. Only 0.4 percent of cultivated land is under irrigation. The sector is predominantly on a smallholder basis. About 90 percent of farm holdings are less than two hectares. The majority of food crops are intercropped. The main industrial crops include cocoa, oil palm, cotton, kola, and rubber. The starchy and cereal staples include cassava, cocoyam, yam, maize, rice, and millet. The fruits and vegetables cultivated include pineapple, citrus, banana, mangoes, pepper, tomatoes, onions, and okra. The major livestock produced consist of cattle, goats, and sheep. There is also some rearing of pigs and poultry [3].

In 2002, the Government of Sierra Leone developed the Food and Agriculture Sector Development Policy (FASDEP I). The focus of this policy is to provide a holistic policy framework in the agricultural sector with an emphasis on the linkages among cultivation and marketing and strengthening the private sector as the engine of growth. Based on the successes and lessons from this policy, FASDEP II was developed in 2007 with an emphasis on the sustainable utilization of all resources and the commercialization of activities in the sector with market-driven growth in mind. The policy objectives of FASDEP II are the following:

- Food security and emergency preparedness,
- Improved growth in incomes,
- Increased competitiveness and enhanced integration into domestic and international markets,
- Sustainable management of land and environment,
- Science and technology applied in food and agricultural development,
- Improved institutional coordination.

The policy of FASDEP II is targeting fewer strategic commodities than in the first phase of FASDEP I. The strategic commodities will see an improvement in productivity of the commodity value chain [4]. These strategic commodities are maize, rice, yam, cassava, and cowpea. To implement the medium-term programs of FASDEP II [5], the Government of Sierra Leone has developed the Medium Term Agriculture Sector Investment Plan (METASIP). The investment plan is to achieve an agricultural GDP annual growth of at least 6 percent and government expenditure allocation of at least 10 percent of the national budget within the plan period [6]. The detailed review of Sierra Leone's agricultural policy will be captured in the literature review. Rice has become one of the major staple cereals in Sierra Leone. It is the second-largest cereal consumed after maize. This is due largely to increasing urbanization and the ease with which it is prepared. About 70 percent of the total rice consumed in Sierra Leone is in urban areas, mainly in the capital, Freetown [7]. In 2016, the estimated net consumption of rice was 150,400MT and a per capita consumption of 24 kg per annum [8]. The Government of Sierra Leone predicts that the nation will continue to see an increase in consumption levels due to rapid population growth and urbanization [9].

Rice varieties are mainly characterized by Asian (Oryza sativa) and African (Oryza Glaberrima) varieties. The well-known Asian varieties are Indica and japonica. Both varieties have long grains but the Indica kernels are longer than the Japonica kernels. The Indica and japonica varieties are broad names for rice groups that can further be characterized based on aroma into either aromatic or non-aromatic [10]. More information is provided in the literature review on the types of rice varieties which is an important consideration to study the rice sub-sector in Sierra Leone. There are about 30 local rice varieties cultivated in Sierra Leone. They are referred to as local in the sense that although these varieties are indices, farmers have been cultivating them in Sierra Leone for a long time. Due to limited information on names and characteristics of varieties, identification of these varieties is difficult. However, some identified non-aromatic varieties include short grain, Long grain, WITA-7, IET6279, GR18, Blue plate, IR5 and NERICA 2 whiles the aromatic varieties include Jasmine 85, Marshall, Ex-Baika, Ex-Hohoe and NERICA 1. These varieties are mainly multiplied by farmers and their level of purification is doubtful [11]. Sierra Leone's rice cultivation has increased from 101,000MT in 2013 to 122,000MT in 2017 representing an increase of 61 percent. Over the same period, the rice area under cultivation increased from 80,000 ha to 91,000 ha representing about 55 percent increase. The yield per hectare also increased by about 9 percent from 2.16MT/ha to 2.35MT/ha over the same period. It can be deduced from these statistics that the observed increase in cultivation was significant as a result of an increase in acreage cultivated.

Only about 60 percent of paddy cultivation is converted into milled rice. The remaining 40 percent is lost in the milling process due to inefficient rice milling practices and rice mills. In 2013, milled rice was estimated at 90,000MT [12]. Although rice cultivation has significantly increased over the period, Sierra Leone's domestic cultivation falls short of consumer demands, thus making Sierra Leone a net importer of rice. Sierra Leone's rice import bill has been on the rise. Over the period 2010 to 2018, imported rice increased from 90,256MT to 130,465MT representing about a 190 percent increase in imports. Over the same period, the import bill increased from US$55.03 million to US$180.17 million. Rice imports attract 40 percent in taxes and levies on the cost, insurance, and freights (CIF) price. This comprises of:

- Import duty -20%,
- Value added tax (VAT)-12.5%,
- National health insurance (NHIS) levy-2.5%,
- Export development and investment fund (EDIF) levy-0.5%,
- Inspection fee-1%,
- ECOWAS levy-0.5%.

There is also a Sierra Leone Customs Network (SLCNET) tax of 0.4 percent charged on free on board (FOB) bases. The imported rice is of better quality and also commands a higher price relative to the local rice. In 2012, the average domestic market price of imported non- aromatic rice was Le 120,000 per 50kg bag compared to Le 110,000 per 50kg for the local rice, a 12.4 percent difference. Sierra Leone imports most of its rice from Vietnam, Thailand and the United States of America [13].

Another challenge faced by the locally produced rice is its relatively poorer quality compared to imported rice. A study by the Japanese International Cooperation Agency (JICA) on the quality of locally milled rice shows that in 2006 about 88 percent of locally milled rice is either of grade 4 or grade 5 quality. Only 4.3 percent of locally milled rice is grade 2 and none is grade 1 among locally milled rice. However, about 56 percent of imported rice is grades 1 and 2. The average grade of domestic rice is 4.7 and that of imported rice is 2.8. These classifications are based on the Sierra Leone Standard's Board classification of cereals, pulses, and legumes. The smaller value indicates higher quality. The main cause of the low grade of domestic rice is the high rates of broken rice. The adherence to the proper moisture content from the period of the harvest to the time of milling is required to reduce the problem of broken grains [14]. Although sophisticated rice mills play an important role in the final quality of rice, it is not the panacea to the problem of broken grains and low quality. The quality of rice comes mostly from the field. The farmer must be in control of many of the quality factors to be able to guarantee quality rice. These factors include weather, pests, diseases, weeds, varieties, timing, irrigation, planting, and harvesting but, unfortunately, most of these factors are out of the smallholder rice farmer's control due to his tools and circumstances [15]. The Government of Sierra Leone and its development partners through the Ministry of Agriculture, Forestry and Food Security(MAFFS) and have initiated some projects in the rice sector to address some of these issues. The interventions that have either been implemented or are currently being implemented include the following: The NERICA (New Rice for Africa) Rice Dissemination Project (NRDP).

This is a group of Indica rice varieties that have been developed for Africa that combines the high yielding attributes of O. Sativa and the resistance of O. glaberrima. The goal of the NERICA Rice Distribution Project is to contribute to poverty reduction and food security through enhanced access to high yielding NERICA upland rice varieties. The objectives of the project are to contribute to increasing locally produced rice for food security and to conserve foreign exchange earnings through import substitution. Ten districts in four regions benefited from this project. The NRDP has four components comprising of technology transfer, cultivation support, capacity building, and project coordination. The project has established a community seed multiplication system where seed grower groups have been trained to produce certified seeds to farmers in the districts under the project. Also, the project has carried out a test on fertilizer requirement levels for NERICA varieties for the three agro-ecologies (savannah, transitional and forest) in Sierra Leone. Furthermore, three rice milling centers have been built in Bo, Bombali, and Kenema districts each comprising of a store, milling house, a 1000-1200kg per hour capacity milling equipment, and drying floors. The duration of the project was from 2004 to 2009.

The Sustainable Development of Rain-Fed Lowland Rice Cultivation Project: The goal of this project is to enhance the productivity and profitability of rice farming in rain-fed lowland areas in the Northern and Southern regions of Sierra Leone. The expected project outputs are the development of a technical package of improved rain-fed lowland rice cultivation, verification of the methodology to improve the farming support system for sustainable rain-fed lowland rice cultivation and establishment of a dissemination procedure of a model for sustainable rainfed low land rice development. Some areas of focus are land development and rice cultivation technology, postharvest technologies such as threshing, milling, and packaging to improve the quality of rice. The duration of the project lasted from 2009 to 2014.

The Rice Sector Support Project: The goal of this project is to improve the livelihood of poor farmers in the targeted regions through the development of a sustainable economic activity based on the natural potential of the region. The Northern, Southern, Eastern, and Northwestern parts of the country are taking part in the project. The three specific objectives of the project consist of (i) support of rice value-chain in Sierra Leone through land development based on the reclamation of 75 valley bottoms, facilitating access to credit for the stakeholders involved in the rice value-chain and institutional capacity development in credit service delivery, capacity building for the stakeholders through support to farmer-based organizations (FBO) and apex organizations and adapted research experiments on rice cultivation, processing technologies, and farming systems, (ii) further enhancing the national organization of the rice sector by providing support to the Sierra Leone Rice InterProfessional Body (GRIB) and (iii) implementing applied research activities to define adapted cropping systems fitting the natural conditions of northern Sierra Leone and the farmers' social and economic situations. The duration of the project is from 2013 to 2016.

The Inland Valley Rice Development Project: The objective of this project is to enhance food security, reduce importation of rice and increase incomes of smallholder rice producers, traders, and processors through increased cultivation of good quality rice. Sierra Leone has numerous inland valleys. Inland valley rice cultivation is more profitable than both conventional irrigation and upland cropping provided water management is improved and farmers adopt improved rice cultivation practices. The project was to provide simple, low-cost water management structures (weirs, dikes, and canals), use of improved cultivation inputs and post-harvest management practices. The project operated in 9 communities in 3 regions in Sierra Leone. The project also promoted the cultivation of the aromatic varieties Jasmine 85 and Marshall. The duration of the project was from 2004 to 2008[16].

1.2 Problem Analysis

Over the past decade and a half, Sierra Leone's rice sub-sector has attracted the attention of stakeholders and policymakers largely due to the increase in consumption and the effects of its rising import bill on the economy. Sierra Leone has the appropriate agronomic conditions to produce rice throughout the year [17]. These favorable conditions coupled with a potential domestic market of about 7.7 million consumers, creates great opportunities for the development of a vibrant rice sub-sector. However, there are numerous constraints in the rice sub-sector in Sierra Leone that stifles the rice cultivation opportunities that the right agronomic conditions present. Structural constraints, namely, poor agronomic practices, low usage of agrochemicals, lack of homogenous seeds of demanded varieties, low farm mechanization resulting in high losses, poor quality of milling facilities and over-dependence on rainfall within the rice subsector debilitate producers taking advantage of the growing market opportunities for their produce [18].

For example, in 2013, about 6 percent of the rice produced in Sierra Leone came from the three northern and Northwestern regions[19]. About 95 percent of that rice is parboiled while most Sierra Leonean consumers prefer rice that has not been parboiled. Parboiling is the process of soaking, steaming and drying paddy rice before it is milled. Rice farmers resort to this process when their paddy rice has dried too much in the field. The process of parboiling reduces the percentage of broken rice during milling. Even though the parboiling process enhances the nutritional value of the rice, it is an additional cost to processors. Therefore, in the Sierra Leonean context, parboiling is an inefficiency process that could be reduced. The cost of this inefficiency is estimated to be over US$20 million, a cost that could be avoidable through improved and timely harvesting [20]. Furthermore, the dependence of farmers on rainfall and the subsistence nature of most farm holdings affect the productivity of rice farmers. For example, as of 2008, 84 percent of agricultural land under rice cultivation is rain-fed [21]. In 2012, the average yield of rice cultivation was 2.2 MT/ha. However, the achievable yield is 4.5 MT/ha which is possible on farms where more effective extension and recommended technologies have been used [22]. According to the Africa Rice Center [23], due to the large share of rain-fed rice and subsistence-based rice farming systems, there is limited growth of aggregate productivity of rice in Africa. Improvement in rice yield, therefore, plays a critical role in feeding the African population.

Sierra Leone's increasing rice import bill puts pressure on the exchange rate. An additional direct effect of this rising import bill is the challenge it poses to the numerous smallholder rice farmers who have to compete with the better processed imported rice. The majority of domestic rice supplied to the market is by smallholder farmers who are mostly considered poor. Furthermore, these smallholder rice farmers are also confronted with the issue of increasing prices of cereals and their price volatility on the international market. Increasing prices of cereals and their volatility has an enormous negative impact on poor households since these households have to spend more on food expenditure (IFPRI, 2012). Also, it can be stated that there is a gap between Sierra Leonean rice consumers' preferences and the rice being produced by the local rice sector. The importation of rice is good news too. The increase in consumption recorded over the years is not only an increase in volume but also an increase in the quality of rice and aromatic varieties in the total rice import mix. This is evident from the fact that the share of broken rice in total rice imports is on the decline. Broken rice or broken kernel is defined as rice grains that are less than three-fourth of the whole grain or kernel (USDA, 2009). Between 2008 and 2009, broken rice imports fell from 70 percent to 63 percent of total rice imports [24]. This shows consumers' changing preference for improved quality long grain rice and also increasingly for aromatic rice varieties. The benefit of imports to consumers is that they pay lower prices in terms of the quality of imported rice they buy as against the domestically produced one. Also, they have a wider variety to choose from and this takes care of every consumer's budget constraint.

Based on the Government of Sierra Leone's evolving policies in the rice sub-sector, the researcher postulated that the government and stakeholders in the rice sub-sector have realized the changing preference of most rice consumers in Sierra Leone for better quality, long and aromatic rice varieties. In this regard, one important step in meeting the demand of consumers is the establishment of the Sierra Leone Rice Inter-professional Body (SLRIB). SLRIB is the main body that organizes private sector stakeholders and advocates for a favorable policy environment that creates incentives in the rice value-chain for actors at every step, from cultivation to consumption[25]. Among SLRIB's programmes is the quality aromatic rice programme. The programme is to develop a market for raw milled aromatic rice by promoting the best domestic aromatic varieties to be grown by farmers. Some of the domestic romantic rice varieties currently in Sierra Leone are Marshall, Ex-Baika, Aromatic Short, Basmati Pushawa and Jasmine 85 [26].

However, the improvement of the farming practices and rice varieties of the smallholder rice farmers coupled with better post-harvest handling of rice would improve the competitiveness of these farmers against rice imports and consequently, play a pivotal role in the development of Sierra Leone's agricultural sector [27]. Therefore, the primary research question of this study is, what opportunities do the current state of Sierra Leone's rice sub-sector offer compared with the rice imports? In analyzing the current state of rice cultivation and opportunities in Sierra Leone, the answering of the following specific research questions will address the primary research question above:

I. How has Sierra Leone's rice sub-sector responded to consumers' growing demand for quality and aromatic rice varieties?
II. What are the key characteristics of the rice distribution network in Sierra Leone to respond to these consumers' preferences?
III. What would be the economic effects of a change in the government's agricultural and trade policy on the rice sub-sector in Sierra Leone to respond to these consumers' preferences?

1.3 Research Organization

The rest of this paper is organized as follows: Section II, related work is reviewed generally on rice and the methodology used in the research. This section entails a brief description of rice, the types of rice and a brief history of the origin of rice. The section also looks at rice cultivation and trade in the world and Africa and the agricultural policy framework in Sierra Leone and previous studies on Sierra Leone's rice sub-sector. It ends with the various trade theories, the Armington model and previous studies on the Armington model. Section III describes the methodology of the research. It covers topics like the study area giving a general overview of the economic activities in Sierra Leone, the population and the agroecological zones in the country. It also covers the data used in this study stating the source of the data, the nature of the data, the processes that the data under went before it was used in this research among others. The section also addresses the method of analysis employed in addressing the various objectives of this study. The theoretical framework of the Armington model will be present. Section IV, the Armington based partial equilibrium model is specified. The model is described in details and the various equations involved in the model will be specified. Section V, the results of the research are presented and explanations offered. This section ends with some concluding remarks and recommendations.

II. Review of Related Work

2.1 General Review on Rice

Rice is a cereal crop. The rice plant (Oryza species) belongs to the grass family (Gramineae). There are both wild and cultivated rice. There are two cultivated species of rice. They are the Oryza sativa the Asian rice which is grown in most parts of the world and Oryza glaberrima which is grown in some parts of West Africa [28]. The O. Sativa specie contains two major sub-species: japonica and indica. These sub-species came about as a result of hybridization-differentiation-selection cycles. Farmers also carried the O. sativa specie to different eco-geographical regions. The japonica sub-specie is adapted to both temperate and tropical upland regions while the indica sub-specie is adapted to the tropics [29]. Rice is rich in genetic diversity. There are more than 117,000 types of rice, including modern and traditional varieties, and wild relatives of rice held by the International Rice Gene bank [30].

2.1.1 Types of Rice Varieties: The type of rice can be classified based on various characteristics [31]. Rice classified based on form can be either:

***Rough or paddy rice*:** This is rice that has not been milled and therefore, has the hull and bran layer still attached to the kernel.

Brown rice: This is rice that has the hull removed but the bran layer is still attached to the kernel.

Milled rice: This is rice that has both the hull and bran layer removed. The greater the degree of milling the more the bran layer is removed and the more polished the grain becomes.

When rice is classified based on eco-geographical regions, rice can be either:

1. ***Indica rice:*** this is a group of rice types that are usually grown in tropical and subtropical areas. It is usually long grain in nature and, when cooked, the grains do not stick to each other and remain light and fluffy [32].
2. ***Japonica rice:*** this is a group of rice types that are usually grown in temperate climates. The grains of japonica rice are more rounded than the grains of the indica type. When cooked, the grains stick to each other and are moist.

When rice is classified based on aroma, rice can be either aromatic (fragrant) rice or non- aromatic (non-fragrant) rice. Aromatic rice has a scented smell when cooked and the non- aromatic rice does not. The well-known traded aromatic varieties are Thai jasmine and basmati (which means "queen of fragrance") from India and Pakistan. Jasmine and basmati rice are both long grains from the indica group of rice. One distinguishing factor between them is that when cooked, the jasmine variety cooks moist and expands in width while the basmati variety which has a slender shape elongates [33].

There are many uncertainties about the exact time and place where the first development of the domesticated species occurred. However, there is enough archaeological evidence to show that the domestication process occurred in Thailand and China. In Thailand, the archaeological evidence shows potsherds with an imprint of both grain and husks of O. Sativa on them in the area called Korat. Also, plant remains were discovered in Spirit Cave on the Thailand-Myanmar border. In China, the evidence shows that the middle Yangtze and upper Huai Rivers are the two earliest places of O. Sativa cultivation. Also, rice and rice farming implements dating back to at least 8,000 years have been found in these areas [34]. The method of cultivation of the crop differed from what was practiced in China and what was practiced in other parts of Southeast Asia. In China, the soil was puddled turning it into the mud and before transplanting seedlings onto it. Compared to other parts of Southeast Asia, the cultivation of rice was through direct seeding under dryland conditions in the uplands and this method was similar to how the wild rice grew [35].

The records show that the first introduction of rice on the European continent may have been in Greece and the neighboring areas of the Mediterranean by returning members of Alexander the Great's expedition to India around 344-324 B.C. From Greece and Sicily, rice spread gradually throughout southern Europe and to a few locations in northern Africa. After its spread in Europe, the Portuguese carried it to Brazil and the Spanish carried it to Central and South America. The records show that rice was first cultivated on the coastal lowlands of South Carolina around 1685. The suggestion is that the crop may well have been brought to the South Carolina coast by slaves brought from Africa. In the 18t h century, rice spread to Louisiana and not until the 20th century was it produced in California's Sacramento Valley. The introduction into California corresponded almost exactly with the timing of the first successful crop in Australia's New South Wales [36].

The time and place of the first domestication of the O. Glaberrima are also clouded in uncertainty. One theory suggests that O. Glaberrima was first domesticated in the Inland Delta of the Upper Niger River (Mali). The species then spread to two secondary centers of diversification one on the coast of Gambia and Guinea Bissau and the other in Guinea forest between Sierra Leone and Cote D'Ivoire. Another theory suggests that O. Glaberima was selected for at several different locations with the forest and savannah areas, where the wild ancestor species O. Barthii grew and was harvested by ancient hunting-gathering human populations. What is clear from these two theories is that the African rice species were being cultivated many centuries before the arrival of the first Europeans on the West African coast [37].

2.1.1 Rice Cultivation Ecosystem

Rice is cultivated under three main ecosystems, namely irrigated rice systems, rain-fed lowland rice systems, and rain-fed upland rice systems [38]. Irrigated rice systems account for 75 percent of the world's rice cultivation. These types of rice farms are concentrated in the humid and sub-humid subtropics and humid tropics especially in Asian countries. Irrigated rice is grown in bundled fields with ensured irrigation for one or more crops a year. The water level is generally maintained at 5–10 centimeters on the field. Averagely irrigated rice farms are small, with the majority in the 0.5 to 2 ha range. Irrigated rice is grown as a monoculture with two or even three crops a year. At present, average irrigated yields are about 5.4 t/ha (IRRI, 2013c). This rice farming system is characterized by high cropping intensity and the intensive use of agrochemicals that can pose an adverse effect on human health and the environment [39].

Rain-fed lowland rice is grown in bundled fields that are flooded with rainwater for at least part of the cropping season. This farming system accounts for about 20 percent of the world's rice cultivation. Due to the high uncertainty in timing, duration, and intensity of rainfall, rain-fed rice is frequently affected by drought and uncontrolled flooding, ranging from flash floods of relatively short duration to deep-water areas that may be submerged under more than 100 cm of water. Because of the uncertainty of the rains and yields, farmers rarely apply fertilizer s and tend to not grow improved varieties. Rain-fed lowland rice is mostly in areas of greatest human poverty: South Asia, parts of Southeast Asia, and essentially all of Africa. Thus, yields are very low between 1 and 2.5 t/ha [20].

Upland rice contributes only 4 percent of the world's total rice cultivation. Upland rice is grown in Asia, Africa, and Latin America. It is the dominant rice cultivating system in Latin America and West Africa. In Central and West Africa, upland areas account for about 40 percent of the area under rice cultivation and employ about 70 percent of the region's rice farmers [40]. Upland rice can be grown in low-lying valley bottoms, undulating and steep sloping lands with lateral water movement. Rice farms are generally unbounded. There is rarely any accumulation of surface water during the growing season. As market access remains limited, most of the world's upland rice farmers tend to be self-sufficient by producing other agricultural crops and animals. Poverty is widespread in these upland areas [18].

2.1.2 World Rice cultivation

Rice is produced in a wide range of environments and under different climatic and geographic conditions from the wettest areas in the world to the driest deserts. Rice is cultivated in over a hundred countries in the world. Rice is the only major cereal crop that is consumed almost exclusively by humans compared to other cereals like wheat which although also cultivated in large proportions is mainly used as animal feed [41]. From table 2.1, total world cultivation was around 723 million tons in 2011. About 90 percent of total world cultivation is from Asia with total cultivation of about 653 million tons in 2011. South America follows Asia with about 26.8 million tons and then Africa is in third place with about 26.5 million tons in 2011. North America has the highest productivity rates of rice cultivation with an average yield of 7.92 t/ha in 2011. Africa has the lowest productivity rate of 2.38 t/ha in 2011 which is below the world average of 4.4 t/ha in 2011. The majority of rice farmers especially those in Asia and Sub-Saharan Africa are smallholder farmers with farm holdings of between 0.5 to 3 hectares in 2011 (IRRI, 2013c). Due to the rich genetic diversity of rice, different countries specialize in the cultivation of different rice varieties.

Table 2.1 Rice cultivation, harvested area and productivity of rice, 2019

	Cultivation Paddy	**Harvested Area**	**Yield Paddy**
Regions	(1000 T)	(1000 Ha)	(T/ha)
Africa	26,531.82	11168.79	2.38
Asia	653,240.40	145270.27	4.5
Europe	4,375.88	725.37	6.03
North America	8,391.87	1059.48	7.92
South America	26,824.82	5046.68	5.32
Rest of the World	3,395.51	854.39	3.97
World	722,760.30	164124.98	4.4

Source: FAO dataset, 2019 [1]

Table 2.2 shows the top ten rice-producing countries in the world in 2010. China is the highest rice-producing country in the world with the cultivation of 197.212 million tons representing about 34 percent of the top ten producing countries. China is followed by India and Bangladesh with cultivation levels of 120.620 million tons and 66.411 million tons respectively. Table 2.2 also shows that the top eight countries in rice cultivation all come from Asia. Interestingly, none of the top ten countries are from either Africa or Europe.

Table 2.2 Top ten rice producing countries in the world in 2010

Country	**Million tons**
China	197.212
India	120.620
Indonesia	66.411
Bangladesh	49.355
Vietnam	39.988
Myanmar	33.204
Thailand	31.597
Philippines	15.771
Brazil	11.308
USA	11.027

Source: FAO dataset, 2019

2.1.3 World Rice Trade

It could be noted that from figure 2.1, the top three rice exporting countries are Thailand, Vietnam, and Pakistan with exporting volumes of 6.902 million, 3.411 million and 2.517 million tons respectively in 2009. China which is the highest rice-producing country only exports 0.622 million tons of its rice. This makes China the seventh in rice exporting countries. Egypt is the only African country among the top ten rice exporting countries in the world with export of 0.560 million tons in 2009. Italy is the eighth rice exporting country in the world and the only country from Europe among the top ten with the export of 0.622 million tons in 2009.

The results of the top ten rice importing countries in the world in 2009 are indicated in table 2.4. The Philippines imported the most rice in the world to a tune of 1. 752 million tons. This is followed by Saudi Arabia and Malaysia in second and third positions with import values of 1.258 million tons and 1.055 million tons respectively. Three countries from Africa are among the top ten rice importing countries.

[1] The dataset can be found on the Food and Agricultural Organization, 2019 http://www.fao.org/home/en/

GSJ: Volume 8, Issue 3, March 2020
ISSN 2320-9186

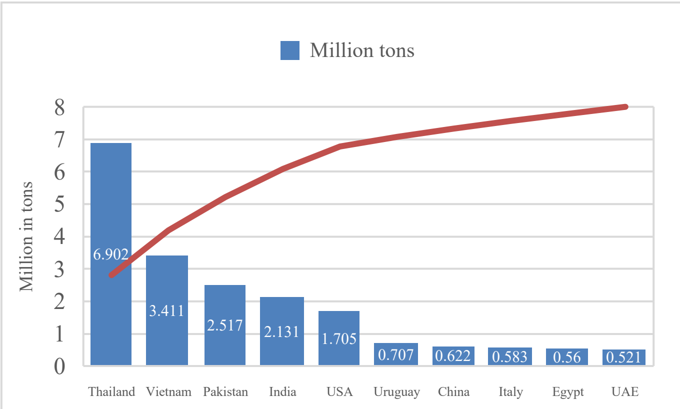

Figure 2.1: Top ten rice exporting countries in the world in 2009 (Source: FAO dataset, 2019)

They are Cote d'Ivoire, South Africa, and Cameroon. Cote d'Ivoire is in fourth in the world rankings with an import value of 0.865 million tons, followed by South Africa in seventh with imports of 0.730 million tons and Cameroon in tenth with an import value of 0.463 million tons. The United States of America is the ninth country among the top ten rice importing countries with imports of 0.539 million tons. As indicated in table 2.2, the United States of America is the tenth country among the top ten rice producing countries and, from table 2.4, it is the fifth country among the top ten exporting countries with exports of 1.705 million tons. Therefore, from tables 2.2, 2.4 and figure 2.1 the figures about the United States of America are maybe an indication that the United States of America does not produce enough of the rice varieties that its consumers want and therefore imports those varieties and exports the other varieties that it produces.

Table 2.4 Top ten rice importing countries in the world in 2009

Country	Million tons
Philippines	1.762
Saudi Arabia	1.258
Malaysia	1.055
Cote d'Ivoire	0.865
Iran	0.780
Iraq	0.755
UAE	0.731
South Africa	0.730
USA	0.539
Cameroon	0.463

Source: FAO dataset, 2019

2.1.4 Rice Cultivation in Africa

Africa was the third-largest producer of rice in the world in 2011 with an estimated value of 26.5million metric tons. From table 2.5, the growth in rice cultivation in Africa has been fairly constant over the period 1990 to 2009. However, between 2010 and 2011, the growth in rice cultivation reduced due to drought and floods in most African countries in 2011 [42]. Climatic conditions have a significant impact on rice cultivation because most rice farms in Africa are heavily dependent on rain [29]. Over the past two decades, the land under cultivation has also increased. Between 1990 and 1999, the average harvested area of rice was about seven million hectares but this has increased to over ten million hectares of land. This increase in land for rice cultivation is reflected in the average annual growth rate of 2. 5 percent for the period 1990 to 1999 compared to the high growth rate of 6.2 percent recorded between 2010 and 2011.

Progress has not been made in terms of rice yields in Africa. During 1990 and 1999, the yield was 2.15 t/ha and this rose to 2.42 t/ha between 2010 and 2011. This brings into sharp focus the fact that the increase recorded in cultivation levels was largely attributed to increased land for rice cultivation. Rice is the fastest-growing food staple in Africa [1]. During the period 1990 to 1999, the annual growth rate of rice consumption was 3.3 percent but this increased significantly to 4.1 percent from 2000 to 2009. The disaggregation of the 4.1 percent on regional block basis shows that Central Africa increased its rice consumption by 9 percent annually followed by East Africa, West Africa, Southern Africa, and North Africa with increments of about 6 percent, 4 percent, 3 percent, and 1 percent respectively.

West Africa is the largest producer of rice in Africa. During the period 2010 and 2011, the region produced about 12 million MT of rice out of about 26 million MT representing about 46 percent of the total rice produced by the continent. West Africa has the second-lowest yields of 1.99 t/ha on the continent. Central Africa has the lowest yield of 1.02 t/ha and North Africa has the highest yield of 9.39 t/ha. This shows the great potential West Africa has to supply the continent's rice demands if it is being able to raise its yield to those of the North Africans.

In a recent study by Wopereis (2013) of the Africa Rice Centre, a trend analysis of rice cultivation was carried out before and after the 2007/2008 rice crisis. Maio et. al[43] used data from the United States Department of Agriculture (USDA). The findings show that an increase in yield accounts for about 71 percent of the increase in paddy rice cultivation in Sub-Saharan Africa whereas, before the rice crisis of 2007/2008, yield accounted for only 24 percent of the increase in cultivation. Also, the increases in cultivation attributed to the expansion of land declined from 76 percent before the crisis to 29 percent. The results also show that the average rice yield in Sub-Saharan Africa increased by about 11 kg per ha per year between the periods 1961 to 2007 however there was a rapid increase of about 108 kg per ha per year from 2007 to 2012. This drastic increase in yields occurred despite drought and floods in several African countries in 2011 and 2012. This is a testimony to increased use of technological innovation such as improved varieties and improved management in general.

2.1.5 Previous Studies on Sierra Leone's Rice Sub-Sector

Sierra Leone's rice sector has attracted the attention of stakeholders and policymakers over the past decade due largely to the increase in consumption and the rising import bill. This has led to studies [9, 16, 44] examining different aspects of the sector to provide a solution for a sustainable supply of rice to consumers at reasonable prices and also developing the rice sector.

According to Seck et al [13], Sierra Leone has a high import rice penetration ratio. The import penetration ratio is calculated as the ratio of total imported rice to total local rice cultivation based on a 65 percent milling yield rate for paddy rice. In 2009, Sierra

Leone had a rice import penetration ratio of 72 percent although this was a decline from 81 percent in 2003. Given this high import rice penetration ratio and holding all other things constant, increasing imported rice prices through tariffs could directly increase domestic rice price and this can jeopardize the food security needs of the poor. Using monthly wholesale prices of domestic rice and imported rice collected by the Statistical Research and Information Directorate (SRID) of the Ministry of Food and Agriculture- Sierra Leone, Seck et al [13]estimates the response elasticity of local rice price to imported rice price. The results show that a 10 percent change in the wholesale price of imported rice yields about 9.13 percent change in the wholesale price of local rice. Seck et al [13] recommend that policymakers should avoid policies that increase the price of imported rice because they would lead to increases in local rice prices, resulting in rice becoming more expensive for income constrained consumers and thus increasing food insecurity. Furthermore, effective policies to enhance the competitiveness of Sierra Leone's local rice sector should be explored from the market perspective and not from an import substitution perspective. The focus must include the development of a niche market that appreciates the higher nutritional characteristics of Sierra Leone's local rice and drive cultivation and sale in those markets, be they local or foreign.

being imported. This segment of the market is expected to increase to 1.1 million MT by 2017. To effectively compete in this market, there is a need to significantly increase yield, improve harvesting practices and improve mills and grading. In the long term, processors must work to eliminate debris and stones from the milled rice. Negin [34] concludes that capturing this market entirely would require investment to increase the area planted for aromatic rice by roughly 125,000 hectares. Investment in large- scale farms with robust out-grower schemes and smallholder involvement may be limited.

Johnson et al[45] argue that Sierra Leone has enormous potential to expand its rice cultivation in the short term through improved production and post-harvest practices and also shift to long grain aromatic varieties that compete more favorably against imports. To achieve this, local rice cultivation and processing must match the quality standards of imported rice. Also, the yield per hectare needs to be increased and simultaneously, the cost of producing high-quality rice needs to drastically decrease. Such required productivity can be achieved through a well-organized network of service providers and processors to strengthen seed systems starting from breeding, seed cultivation, and certification and distribution.

Table 2.6 Evolution of cultivation, harvested area, yield and consumption of rice in Africa (1990-2011)

	1990-1999	2000-2009	2010-2011
Average total per year:			
Cultivation (1000MT)	14965.10	20063.33	26205.07
Harvested area (1000Ha)	6942.71	8485.28	10842.96
Yield (MT/Ha)	2.15	2.36	2.42
Consumption (1000MT)	13381.90	19518.80	
Average annual growth rate:			
Cultivation (%)	3.54	3.38	2.53
Harvested area (%)	2.46	2.66	6.20
Yield (%)	1.06	0.70	-3.25
Consumption (%)	3.27	4.11	

Source: FAO dataset, 2019

Similarly, [38] argues that Sierra Leone's rice market is highly segmented by variety, degree of processing, grain quality, and origin. Consumers prefer rice that is free from debris and stones, straight milled rice before parboiled rice, imported rice before locally produced rice and aromatic rice before non-aromatic rice. Also, there is a large technological gap between current cultivation and processing and the kind of cultivation systems that are required to compete with imports and meet growing demand. However, in the short term, the focus should be on opportunities that are not requiring large-scale investment or major shifts in consumer behavior. Rice farmers can compete in the 25 percent broken indica rice market which they currently control one-third. They can increase this proportion and substitute for the remaining 10,000MT of imports, a US$ 25 million opportunity at current prices.

In the medium term, there is an opportunity to substitute for the 5 percent broken, non - aromatic, straight-milled rice currently

Also, this network should facilitate access to appropriate mechanization technologies for small-scale and medium-scale rice producers to overcome scarce labour and high labour cost constraints to cultivation. Increased productivity and cultivation volumes will, in turn, stimulate demand for greater investment in milling and storage facilities for cultivation rather than imports [46].

Van Nguyen[47] also analyses the cost of rice cultivation in Sierra Leone. They combined the Policy Analysis Matrix (PAM) and Data Envelopment Analysis (DEA) techniques to evaluate the profitability and competitiveness of maize, rice and soybean cultivation in Sierra Leone. Two alternative profit functions were considered: including family labour in domestic cost factor (conventional PAM) and excluding family labour from domestic cost factor (PAM). The conventional PAM analysis shows that rice farming is not profitable for the observed average farm both in private and social prices. However, the results from the PAM analysis with profit efficient data show that rice farming is profitable under cultivation plans that maximize profits in private prices, but is not profitable in social prices. Conversely, the PAM analysis shows that rice farming is profitable for both the observed average and profit -efficient farmers in both private and social prices. Given the fact that family labour is the most important input in rice cultivation in Sierra Leone, the results point to the ability of rice farming systems in Sierra Leone to create value for farmers and also add welfare gains to the society.

IV. Methodology

3.1 Review of Trade Theories

There is a plethora of theories on trade and economists classify them as classical, neoclassical or new trade theories. These theories start from Mercantilism which states the world has a fixed wealth and you need to take from other countries to increase your wealth to Adam Smith's theory of absolute advantage to David Ricardo's famous theory of comparative advantage to the Heckscher-Ohlin theory of factor endowments and its resulting spinoffs of the Stolper-Samuelson Theorem and Rybczynski Theorem to the standard trade model which incorporates both the assumptions of the Ricardian theory and the Heckscher-Ohlin theory and finally to the New Trade theory by Krugman which is based on two main features: economies of scale and monopolistic competition to explain the composition of trade.

Adam Smith's theory of absolute advantage and the Ricardian theory of comparative advantage can be classified as classical trade theories. The Heckscher-Ohlin theory and the standard trade model can be classified as neoclassical trade theories. The New Trade theory also called the Krugman model is classified as one of the new trade theories. A brief highlight of some of these theories is discussed below. The discussion on these theories will be drawn from Wen et al[17]. The basis of Adam Smith's theory is that for trade to take place between two countries, both nations must gain. Trade will not take place if one country loses in the process. Therefore, mutually beneficial trade takes place based on absolute advantage. When one country has an absolute advantage over the other country in the cultivation of a good, then both counties gain by each specializing in the cultivation of the good in which it has an absolute advantage. Each country will then exchange the commodity in which it has an absolute advantage in return of the good in which it has an absolute disadvantage. According to Smith, free trade will ensure the efficient utilization of resources in the cultivation of both commodities. According to David Ricardo, a difference in comparative costs of cultivation is the necessary condition for the existence of international trade. The difference in comparative cost is reflected in the cultivation techniques of the country and thus the level of technology of the country. The theory says that technological differences between countries determine how labour is engaged in each country and consumption and trade patterns. The conclusion of the Ricardian theory as in the case of Adam Smith's theory of absolute advantage is that trade is beneficial to all participating countries. This conclusion is against the Mercantilism theory that says that there is a fixed amount of wealth in the world and that the regulation and planning of a country's economic activity are efficient means of improving the wealth of the nation.

3.1.1 Empirical Models

There are equally many empirical trade models as there are trade theories. These empirical models include spatial, market share (Armington), static, dynamic, deterministic, stochastic, structural, predictive, partial equilibrium and general equilibrium models. Depending on what the researcher's interest is, the model developed or used by the researcher can either be one of the above or a combination of two or more [49]. For this study, not all these models will be reviewed but a brief review of the partial equilibrium and general equilibrium models and the Armington hypothesis will be looked at.

3.1.2 Partial Equilibrium Models

Partial equilibrium models are models that analyze only the direct price effects of a shock. These types of models are good for their simplicity and that the direct effects it measures can be fairly close to the total effects. The model is also appropriate when the researcher's focus is on a single or a particular sector and the income and expenditure shares of the sector in the total economy or household's budget are small. However, partial equilibrium models exclude several important effects such as income effects, exchange rate, resource endowments and interactions across markets. Therefore, where the sector under study has many interactions with other sectors, the partial equilibrium model is not appropriate. Generally speaking, all models are assumed to be partial because it is difficult to model or capture all the interactions in the economy. Therefore, it is appropriate to say some models are more complete than others[20, 50, 51].

3.1.3 General Equilibrium Models

Computable general equilibrium (CGE) models are models that attempt to model the whole economy. The models try to incorporate all factors of cultivation, all agricultural commodities and non-farm sectors. An important component of the CGE models is the social accounting matrix (SAM). This allows for the modelling of multi-sectoral, multiclass disaggregation, investment and savings, balance of payment and government budget. With all this components built into the model, the CGM measures both direct and indirect effects of a shock. For policy analysis purposes, CGE models capture changes in real income resulting from price changes and therefore are better for welfare analysis. However, the major setback of these models is that since they may be very large with so many linkages between sectors, it can become a 'black box' where some effects are lost in the analysis. They may be also too expensive to maintain and they are time-consuming [19, 52].

3.1.4 Armington Assumption

The Armington assumption has been widely used since Armington (1969) proposed that goods can be differentiated according to their geographical location. This assumption, therefore, allows for imperfect substitutability between foreign and domestic products. The Armington assumption-based model is constructed on a two or multistage budgeting process. In the first stage, the consumer, in this case, the importing country's total demand (expenditure) is determined and in the second stage, this demand is allocated between different suppliers. The Armington assumption-based model uses constant elasticity of substitution (CES) functional form. This implies that the demands are homothetic and separable across sources of supply. Although several studies have been using the Armington assumption-based model, some limitations of the model have been identified. Some of these studies [53, 54] have used the CES functional forms and others have relaxed the inherent homothetic assumption of the CES and used other functional forms.

Cohen et al[55] tested the Armington assumptions of homotheticity and separability using data from the international cotton and wheat markets. Using parametric and nonparametric tests the results reject the Armington assumptions. The conclusion is that the constant elasticity of substitution is not appropriate for all datasets. It has implications for international trade modeling and computable general equilibrium (CGE) modeling because the Armington assumption is an integral part of its trade equations.

Monke et al[56] used a constant difference of elasticities (CDE) function to study trade in processed food products in France. The CDE model framework is capable of explaining trade flows based on consumer differentiation between the origins of the product. More importantly, it overcomes the problem of homotheticity by allowing for non- homogenous preference among supplies of a given product. The linear homogeneous Armington model is rejected for the majority of the food products but the CDE provided better results. The study also showed that French consumers differentiated products not only based on domestic or imported products but also based on whether it is originating from the European Union or the rest of the world.

Krueger [57] shows that the type of empirical data used can affect the estimation of the Armington elasticities. Sowa et al[58] estimated the Armington elasticities using both multilateral trade data and bilateral trade data. The findings reveal that the Armington elasticities obtained from multilateral trade data are higher than those obtained from bilateral trade data in the intermediate inputs sector. Saito argues that multilateral trade data may not capture the growth of outsourcing and the changes in the composition of intermediate inputs trade and therefore, may result in a bias in the estimates obtained from multilateral trade data sets. Huchet-Bourdon, and Pishbahar (2008) applied the Armington assumptions in their study of rice imports into the European Union. In their study, two key questions are addressed:

Ø "Does the inclusion of import tariffs in the specification lead to different estimated Armington elasticities?";

Ø "When a discriminating tariff is introduced, what happens to the market share of large rice exporters to the EU, especially to the market share of poor countries?" The Armington model was based on two different CES functional forms. They used the conventional CES with its inherent homothetic assumption and also a more relaxed non-homothetic CES functional form. They also estimated the Armington elasticities with and without the inclusion of a tariff and then compared these elasticities. To address the second question, five scenarios with different discriminating import tariff rates were simulated to calculate the changes in the market access of large rice exporters to the EU. The findings of the study show that the more flexible non-homothetic CES functional form gave better results and that the assumption of homotheticity is valid only for specific cases. Also ignoring import tariffs may cause underestimation of the Armington elasticities. For the second question, the findings show that the less developed countries have weak capacity to compete with developed countries such as the USA in accessing the EU market even if there is import tariff discrimination in favor of the less developed countries.

3.2 Study Area

The study area of this study is Sierra Leone. Sierra Leone is a tropical country located in West Africa and the capital is Freetown. Its neighbors are Guinea to the north, Liberia to the South East and the West the Atlantic Ocean. The population of Sierra Leone is about 7.5 million people. About Fifty-five percent are female and forty-five percent are male. The life expectancy is 64 years for men and 66 years for women. Sierra Leone has five administrative regions namely North, Northwest, East, South and Western regions.

The Western region constitutes about thirty-five percent of the total population (SSL, 2018). The gross domestic product (GDP) of Sierra Leone in 2017 was about US$ 5.71 billion [59]. There are six agro-ecological zones in Sierra Leone namely rain forest, deciduous forest, transitional, coastal, Guinea Savannah and Sudan Savannah. These agroecological zones coupled with the vast variety of soils makes the cultivation of different crops possible (MAFFS, 2017). In 2015, the services sector contributed 30 percent to the GDP, followed by the industrial sector with 17.3 percent and the agricultural sector accounted for about 52.7 percent. GDP growth in 2013 was about 4.9 percent. The main export earning commodities are Iron ore, Diamond and cocoa beans. It is also very active in the exportation of horticultural crops like pineapples, mangoes, and citrus. In 2012. Agriculture is still an integral part of the economy and it is dominated by smallholder farmers who are mainly in the food crop sector. Commercial farmers (more than 50 percent of rice farmers) are into the cultivation of rice.

3.3 Dataset Description

The data used for this study is a panel data covering the period 2000 to 2018. The elements of the data set were the annual cultivation levels of rice and maize, the annual consumer prices of rice and maize, the yield of cultivated rice and maize, total cultivated land for rice and maize, and quantities and price of imported rice. The data on domestic elements covers the five administrative regions in Sierra Leone. The imported values were at the national level. The data is a source from the Ministry of Agriculture, Forestry and Food Security, and the Sierra Leone Agricultural Research Institute (MAFFS-SLARI). This is the official government department responsible for the collecting and keeping of Sierra Leone's data on agriculture. The data was very difficult to access. The data is very much aggregated in the sense that it did not provide any break down on the specific details that were required for this study. For example, the data on cultivation levels of rice is not disaggregated into either aromatic or non-aromatic. Therefore before the data is used, further research is done to ascertain an estimate for the proportion of aromatic and non- aromatic rice that make up the rice mix in Sierra Leone. It is after this process that the data is used.

3.4 Method of Analysis

Under this section, the methods and the processes that are used to address the specific objectives of the study are addressed.

Objective I: For objective one, the descriptive analysis will be used to address objective one tables and trend analysis will be used to analyze the evolution of rice cultivation, yield, acreage cultivated and rice import penetration ratio from 2002 to 2013. The expressions that will be used to calculate the observed trends are:

$$\boldsymbol{AVG_{rate}} = \left[\left(\frac{\boldsymbol{Fv}}{\boldsymbol{Iv}}\right)^{\frac{1}{T-1}} - \mathbf{1}\right] * \mathbf{100} \qquad [1.]$$

$$Where\ AVG_{rate} = average\ annual\ growth\ rate\ , Fv = final\ value, Iv = Initail\ value, and\ T = number\ of\ years$$

$$\boldsymbol{IP_{ratio}} = \left[\frac{\boldsymbol{Q_i}}{\boldsymbol{Q_i + Q_d}}\right] * \mathbf{100} \qquad [2.]$$

$$where\ IP_{ratio} = import\ penetration\ ratio, Q_i = quantity\ of\ imported\ rice, and\ Q_d = quantity\ of\ domestic\ rice$$

Objective II: A schema is used to describe the role of the various actors in the rice distribution network in Sierra Leone. It will start from the supply of imports to rice farmers and the role of all the other actors in the network until the final consumer. According to Migot et al [60], marketing channels are the alternative routes of product flows from producers to consumers through a chain of intermediaries. A marketing channel is not different from a value chain. They are very similar in what they represent but a value chain focuses on the value added to a product from the period of input supply to the producer until it reaches the final consumer and the value added by the intermediaries within the chain. A marketing channel focuses more on the actors in the value chain and the roles they play. It can be said that a distribution network and a value chain are different sides of the same coin.

Objective III: The Armington based partial equilibrium model is developed. The model is further elaborated upon below. The mathematical derivation of the Armington elasticity below forms the bases for the equations that will be specified in building the partial equilibrium model.

A Mathematical Derivation of the Armington Equation: Given a well-behaved CES utility function and weakly separable assumptions in a consumer's preference between imported and domestic goods, the Armington elasticity can be derived as follows. This derivation is based on what is commonly used in trade models [61].

$$\boldsymbol{Q(M, D)} = \left[\boldsymbol{\beta M^{\frac{\sigma-1}{\sigma}} + (1-\beta)D^{\frac{\sigma-1}{\sigma}}}\right] \qquad [3.]$$

$$Where\ M = the\ quantity\ of\ imported\ good,\ D = the\ quantity\ of\ the\ domestically\ produced\ good,\ \sigma = the\ CES\ between\ the\ domestic\ and\ imported\ good,\ \beta = a\ calibrated\ share\ paramter\ in\ the\ demand\ function$$

Let P_m and P_d be the price of imported and domestic goods respectively. The optimum solution for the consumer is to minimize expenditure. This is requires that the prices be made equal to the marginal utility derived from purchasing the associated goods, so that $\frac{dQ}{dM} = P\ and\ \frac{dQ}{dD} = P_d$ Thus differentiating equation [1.] with respect to M and D results in.

$$\boldsymbol{\frac{dQ}{dM} = \frac{\sigma}{\sigma-1}\left[\beta M^{\frac{\sigma-1}{\sigma}} + (1-\beta)D^{\frac{\sigma-1}{\sigma}}\right]^{\frac{1}{\sigma-1}}\left(\frac{\sigma-1}{\sigma}\right)\beta M^{\frac{-1}{\sigma}}} \qquad [4.]$$

$$\boldsymbol{\frac{dQ}{dM} = \beta M^{\frac{-1}{\sigma}}\left[\beta M^{\frac{\sigma-1}{\sigma}} + (1-\beta)D^{\frac{\sigma-1}{\sigma}}\right]^{\frac{1}{\sigma-1}}} \qquad [5.]$$

$$\frac{dQ}{dM} = \frac{\sigma}{\sigma-1}\left[\beta M^{\frac{\sigma-1}{\sigma}} + (1-\beta)D^{\frac{\sigma-1}{\sigma}}\right]^{\frac{1}{\sigma-1}}\left(\frac{\sigma-1}{\sigma}\right)(1-\beta)\beta M^{\frac{-1}{\sigma}} \qquad [6.]$$

$$\frac{dQ}{dM} = (1-\beta)D^{\frac{-1}{\sigma}}\left[\beta M^{\frac{\sigma-1}{\sigma}} + (1-\beta)D^{\frac{\sigma-1}{\sigma}}\right]^{\frac{1}{\sigma-1}} \qquad [7.]$$

$$Given\ that\ \frac{dQ}{dM}\ and \frac{dQ}{dD}\ must\ be\ equal\ to\ P_m\ and\ P_d\ respectively\ the\ price\ ratio\ \frac{P_m}{P_d}\ can\ be\ rewritten\ as:$$

$$\frac{P_d}{P_m} = \frac{\frac{dQ}{dD}}{\frac{dQ}{dM}} = \frac{P_d}{P_m} \qquad [8.]$$

$$= \frac{(1-\beta)D^{\frac{-1}{\sigma}}\left[\beta M^{\frac{\sigma-1}{\sigma}} + (1-\beta)D^{\frac{\sigma-1}{\sigma}}\right]^{\frac{1}{\sigma-1}}}{\beta M^{\frac{-1}{\sigma}}\left[\beta M^{\frac{\sigma-1}{\sigma}} + (1-\beta)D^{\frac{\sigma-1}{\sigma}}\right]^{\frac{1}{\sigma-1}}}$$

$$= \frac{(1-\beta)D^{\frac{-1}{\sigma}}}{\beta M^{\frac{-1}{\sigma}}}$$

$$\boldsymbol{\Rightarrow \left(\frac{M}{D}\right) = \left(\frac{\beta}{1-\beta}\right)^{\sigma}\left(\frac{P_d}{P_m}\right)^{\sigma}} \qquad [9.]$$

$$Taking\ the\ logarithmic\ form\ of\ equation\ [4]\ will\ result\ in\ the\ simple\ linear\ expression\ of\ the\ Armington\ equation$$

$$\boldsymbol{\Rightarrow ln\left(\frac{M}{D}\right) = \sigma ln\left(\frac{\beta}{1-\beta}\right) + \sigma ln\left(\frac{P_d}{P_m}\right)} \qquad [10.]$$

$$\boldsymbol{Where\ \sigma ln\left(\frac{\beta}{1-\beta}\right) = calibrated\ constant, and\ \sigma = Armington\ elasticity\ of\ substitution}$$

***Model Specification and Justification*:** As stated earlier, partial equilibrium analysis is appropriate when the income effect of a pricechange is small. Also, partial equilibrium analysis can be used when the total expenditure of the commodity of interest in the total household food budget is small. Therefore, partial equilibrium analysis is used for this study because rice which is the focus of this study contributed about 20.2 percent to the total food expenditure of the household in 2012/2013. In the same period, the rice income share of total household income was about 0.9 percent [62]. This percentage is less than one-tenth and, therefore, it is appropriate to rely on a partial equilibrium analysis of the rice sub-sector in Sierra Leone. The other aspect of the model has to do with the heterogeneous nature of rice. There are two bases for product differentiation. The first is based on the Armington assumption which has to do with the origin of the product. So the consumer has two choices: either to consume domestic or imported rice. The second is based on the variety of rice. Also, here the consumer can choose between aromatic and non-aromatic rice. Therefore, the consumer has a total of four options to choose from: domestic aromatic, imported aromatic, domestic non-aromatic and imported non-aromatic.

Assumptions of the Model: There are three sides to the model, the cultivation (supply) side, the consumption (demand) side, and the closure (equilibrium) side. The assumptions used in the model are:

- *Rice is differentiated based on the country of origin (Armington assumption)*
- *Rice is also differentiated based on variety (aromatic and non-aromatic rice)*
- *There are no rice exports*
- *There is import tax and other taxes levied on imported rice*
- *There is self-sufficiency in maize cultivation (no import or export)*
- *Farmland is either used for rice or maize cultivation*
- *Consumers choice of cereal is between rice and maize*
- *There is perfect competition, therefore, producer prices equals consumer prices*

***Equations of the Model*:** For the cultivation side, the farmer's first decision is to determine how much input (land) he or she will allocate to the cultivation of rice and maize. The determination of rice and maize to produce depends on the relative prices of the two commodities. Therefore, a relation can be established between the cultivation possibility function of rice and maize, the relative supply of rice and maize and the relative prices of the commodities. The functional form for transforming his inputs (land) into the cultivation of rice and maize is by the constant elasticity of transformation (CET) function. This is given by:

$$\overline{\boldsymbol{R_{mix}}} = \boldsymbol{CET(CS_R, CS_M)} \Rightarrow \boldsymbol{A_{mix}\left[\alpha_{mix} CS_R^{\beta_{mix}} + (1-\alpha_{mix}) CS_M^{\beta_{mix}}\right]^{\frac{1}{\beta_{mix}}}} \quad [11.]$$

$$Where\ R_{mix} = valuable\ land\ for\ rice\ and\ maize$$
$$CS_R = crop\ supply\ of\ rice$$
$$CS_M = crop\ supply\ of\ maize$$
$$A_{mix} = scale\ parameter\ for\ rice\ and\ maize\ cultivation$$
$$\alpha_{mix} = share\ parameter\ for\ rice\ and\ maize\ cultivation$$
$$\beta_{mix} = transformation\ parameter\ for\ rice\ and\ maize\ cultivation$$

The constant elasticity of transformation between rice and maize (τ_{mix}) which is the ease with which the farmer is choose between rice and maize cultivation is given by the relation:

$$\boldsymbol{\tau_{mix} = \frac{1}{1-\beta_{mix}}} \quad [12.]$$

The optimum relative supply of rice and maize by the farmer is a function of their relative prices and this relation is given by:

$$\boldsymbol{\frac{CS_R}{CS_M} = K_{mix}\left(\frac{P_r^p}{P_m^p}\right)^{\tau_{mix}}} \quad [13.]$$

$$\boldsymbol{K_{mix} = \left[\frac{(1-\alpha_{mix})}{\alpha_{mix}}\right]^{\tau_{mix}}} \quad [14.]$$

$$Where:\ P_r^p = produce\ price\ of\ rice$$
$$P_m^p = produce\ price\ of\ maize$$
$$K_{mix} = constant\ for\ relative\ supply\ of\ rice\ abd\ maize$$

After the farmer has decided on the relative supply of rice and maize, his or her next decision is to determine the relative supply of aromatic rice and non-aromatic rice. The farmer's cultivation function for the cultivation of rice is given by:

$$\boldsymbol{CS_R = CET(CS_{aro}, CS_{naro}) \Rightarrow CS_R = A_R\left[\alpha_R CS_{aro}^{\beta_R} + (1-\alpha_R) CS_{naro}^{\beta_R}\right]^{\frac{1}{\beta_R}}} \quad [15.]$$

$$Where\ CS_{aro} = crop\ supply\ of\ aromatic\ rice$$
$$CS_{naro} = crop\ supply\ of\ nonaromatic\ rice$$
$$A_R = scale\ paramter\ for\ aromatic\ and\ nonaromatic\ rice\ cultivation$$
$$\alpha_R = share\ paramter\ for\ aromatic\ and\ nonaromatic\ rice\ cultivation$$
$$\beta_R = transformation\ paramter\ for\ aromatic\ and\ nonaromatic\ rice\ cultivation$$

3.5 Model Calibration

Calibration is a very important step in the development of a model. Before models are used for simulation purposes, the values of the parameters specified in the functional relations need to be identified. There are two main ways of identifying these parameters [63]. They are (1) the determinist calibration method and (2) the econometric estimation method. The procedure often used is the straightforward calibration method. The underlying assumption of the calibration method is that the economy is assumed to be in equilibrium during a bench-mark or reference period. The bench-mark or reference data set which is the data collected for the study serves as the equilibrium solution for the model so that the model is solved from the equilibrium data for its parameter values. The parameters calculated are then used to run the model to reproduce the empirical data as an equilibrium solution for the model. If all the model parameters are not enough to identify the model, some of the parameter values in this case the CES and CET elasticities are specified exogenously until the model is identified. After the calibration process, simulation can then be performed by applying shocks to the exogenous variables or parameters of the model.

The main setback of the calibration method is that it provides no statistical test of the models' specification since the calculation procedure is deterministic and less precise. The advantage, however, is that fewer data, observations, and calculations are required. The econometric method of calculating parameters is more accurate but when dealing with large models, it requires the calculation of many parameters and the degrees of freedom can become a challenge. Therefore, the econometric method can be unfeasible at times.

In the building of the Armington based partial equilibrium model, the calibration method is adopted. The average of a three year period (2008-2010) is used in computing the missing parameters for the benchmark data set. A three-year average is used because averages eliminate any form of variations in a particular year and therefore give a more deterministic review of the economy. Data use in the model covers land size for rice and maize in hectares, and quantities and prices of rice and maize consumption, rice and maize cultivation, rice imports and the composite quantities and prices on these variables are computed by the author. The data for rice was aggregated and therefore, using previous studies, proportions for aromatic and non- aromatic rice in total rice are apportioned and also the proportions are assigned the imported aromatic and non-aromatic rice in total rice imports.

The constant elasticity of transformation (CET) and constant elasticity of substitution (CES) are exogenously introduced into the model. Different values of these elasticities are used until the model is solved. The model is then verified by baserunning it with the calculated parameters to re-generate the bench-mark or reference data used. It is after this process that the parameter values are used in the simulation phase.

3.6 Simulation Scenarios

In the simulation phase, three simulation scenarios are used. They are (1) agricultural policy shocks, (2) trade policy shocks and (3) world rice price shocks. The effect of these scenarios on rice cultivation, consumption and rice imports are considered. To simulate the agricultural policy shocks, two scenarios are considered. The first is an expansion in total land size (R) allocated to rice and maize cultivation. The land size is increased by 5, 10 and 20 percent. The second scenario is an increase in rice productivity. This simulation is done by decreasing the scale or efficiency parameter for aromatic and non-aromatic rice (AR) by 5, 10 and 20 percent. An increase in productivity implies that to obtain the same level of output, less of the current scale or efficiency parameter is required. This explains why the scale or efficiency parameter of rice is reduced although the effect of an increase in productivity is being simulated. The trade policy scenario is simulated by varying taxes on imported rice. Two situations are considered namely, trade restriction and trade promotion. Trade restriction will be simulated by increasing taxes on imported rice by 5, 10 and 20 percent. Trade promotion will be simulated by decreasing taxes on imported rice by 50, 75 and 100 percent.

The world rice price scenario will be simulated through the cost, insurance and freights (CIF) prices for imported rice. A 5, 10 and 20 percent increase or decrease in CIF prices will depict worsening or improving world rice market conditions respectively. The simulated results are compared with the current state of the rice sub-sector and percentage changes are calculated for cultivation, consumption, and imports of rice varieties and maize.

IV. Results and Discussion

4.1 Trend Analysis of the Rice Sub-Sector in Sierra Leone

The trend in paddy rice cultivation, yield, and acreage cultivated in Sierra Leone from 2007 to 2018 are documented. This shows that between 2007 and 2018, the annual growth rate in cultivation was about 5.8 percent. Examining a shorter period, the display shows that from 2009 to 2015, cultivation has been fairly constant. Over the first seven-year period, average cultivation increased annually by just 0.1 percent. The total percentage change in cultivation over the same period was 0.5 percent. This is quite evident that there was not much growth in terms of rice cultivation in the sub-sector. Cultivation dipped to 185,341MT in 2007, the lowest level over the entire period of the study. However, over the following three-year period (2008-2010), cultivation levels experienced an upward trend. The average annual growth rate in cultivation was 27 percent. However, there was a slight dip again in 2011 to 463,975MT from the 2010 amount of 491,603MT. Taking the 2011 decline into account, the average annual growth rate in cultivation from 2008 to 2011 was 15 percent. The acreage cultivated from 2000 to 2018 increased annually by 5 percent. Over the same period, the average annual growth rate for yield increased by just 0.8 percent. The percentage change in acreage cultivated from 2002 to 2013 is 71 percent while the percentage change in yield is an abysmal 8.8 percent.

From the analysis of the trend so far, it shows that the acreage cultivated accounts more for the growth in paddy cultivation compared to the contribution of yield to total paddy cultivation. Therefore, any percentage change in acreage cultivated will have a greater effect on cultivation levels. The vast majority of rice farmers in Sierra Leone who happen to be mostly smallholder farmers depend largely on rainfall for their farming activities. In 2007 the rains delayed and when they came it was very erratic. Consequently, farmers had to plant late and less land was put under rice cultivation. This led to the drastic decline in cultivation recorded at the end of the year. As a result, rice had to be imported to augment the low cultivation. In 2007, there was also the cereal crisis on the world stage and the price of rice was very high on the world stage. This was transmitted to the local markets in Sierra Leone. The Sierra Leone National Rice Development Strategy (SLNRDS) was a response to mitigate the future occurrence of the hardship occasioned by the crisis of 2007. The SLNRDS can be said to account for the massive investment by MAFFS into the procurement of tractors, building more rice mill facilities, providing subsidies on fertilizer to farmers among other initiatives. This accounts for the high growth experienced between 2015 and 2017.

The decline in rice cultivation recorded in 2011 after the impressive growth from 2008 to 2010 despite the increase in acreage in the same period can be attributed to the Government of Sierra Leone's reduced investment in the agriculture sector. Sierra Leone's rice import from 2007 to 2018 is shown is documented. The outstanding observation is the almost 800,000MT of rice imports in 2003. This is a unique year in the sense that some of this rice was transported to other African countries. The actual quantity that left Sierra Leone cannot be ascertained so it's included in the data with the above explanation. So analyzing the data from 2004 to 2011, the average annual growth rate of rice imports was 11 percent. From 2007 to 2010, there was a downward trend of 10 percent annually. However, in 2011 imports increased again to about 543000MT. This can be attributed to a decrease in domestic cultivation.

Based on Sierra Leone's rice cultivation and imports, the next issue is how dependent is Sierra Leone on imported rice. To calculate this, the import penetration ratio which shows the level at which rice imports make up the total rice mix in Sierra Leone is calculated. From the analyses above, Sierra Leone still depends heavily on rice imports. More than half of the rice consumed in Sierra Leone is imported. Apart from the unique situation of 2003 and therefore, the high import ratio of about 85 percent, the next highest penetration ratio recorded in recent years was in 2007 with a figure of about 80 percent. As earlier stated, the unfavorable climatic conditions of 2007 led to low cultivation and consequently higher imports to make up for the shortfall. The lowest penetration ratio was recorded in 2010 with a value of 52 percent. In 2010, the domestic cultivation was highest at about 464000MT and also government reinstated the 20 percent import tax which temporarily.

The summary of the analysis of objective one shows that rice cultivation, yield, and acreage are increasing. However, rice import is also increasing. Consequently, the rice import penetration ratio in 2011 is 66 percent. The analysis of objective one shows the growing trend in rice cultivation, yield, and acreage. The simulation results from objective three would help determine the magnitude of the effect of increasing land size and rice productivity on rice cultivation, consumption and rice imports removed in 2008 because of the cereal crisis. The generally high import penetration ratio is due to the fact that about 40 percent of paddy cultivation is lost in the process of converting it into milled rice. Therefore, the general improvement in post-harvest handling of rice can go a long way to reduce this dependency on imported rice. The summary of the analysis of objective one shows that rice cultivation, yield, and acreage are increasing. However, rice import is also increasing. Consequently, the rice import penetration ratio in 2011 is 66 percent. The analysis of objective one shows the growing trend in rice cultivation, yield, and acreage. The simulation results from objective three would help determine the magnitude of the effect of increasing land size and rice productivity on rice cultivation, consumption and rice imports.

4.2 Description of the Rice Distribution Network

Most of the inputs used like agrochemical, fertilizers and farm implements by the producers are imported. The seeds are however mostly procured locally. The producers are mostly smallholder rice farmers. However, over the past decade, some medium and large scale rice farms have joined the sector. The producer may sell his or her produce directly in the rural retail market or sell it to local rice processors or aggregators. These processors are individuals who have rice mills and other facilities for drying the rice like cement floors. The large farms have modern rice milling facilities and offer their services to the smallholder producers at a fee. The local processors may also send their semi milled grains for further processing at the large processors. The wholesalers sell both domestic and imported rice. In the local network, they buy their products from producers and have them processed by the local processors or aggregators. These wholesalers are mostly traders, often referred to as 'market women' who sell on the local markets. They are an integral part of the local rice distribution network. They often dominate the local agriculture trade and sometimes influence prices and local trade in Sierra Leone [64].

A study conducted in 2003 by the Overseas Development Institute (ODI) in thirty -two rice producing communities in Sierra Leone showed that most farmers received price information for rice from these traders. Another aspect of the relationship between these wholesalers and the farmers is that the wholesalers or market women provide the farmers with capital and have an informal agreement with the farmers that when the produce is harvested the market women come for the paddy rice. The market women decide the price they pay to the farmers and in the words of ODI, they operate an oligopolistic system which constrains the market and limits innovation (ODI, 2003). The wholesalers sell theirs produces both in the urban and rural retail markets. The retailers then sell the produces to urban or rural consumers.

Rice imports into Sierra Leone are mainly from Asia and the United States of America. There is one major rice importer in Sierra Leone, which is the Commodities Trading Co ltd (CTC). This importer has a number of subsidiaries operating as imported rice wholesalers. Therefore, rice importer has a lot of influence on the imported rice distribution network. This importer sells directly to imported rice wholesalers, rice wholesalers, and some relatively bigger urban retailers. The importer transport the rice from the ports to their warehouse where it is distributed to the various actors down the network. These wholesalers then sell the rice to urban and rural retailers who then sell to consumers. The imported rice distribution network is shorter than the local rice distribution network. The imported rice distribution network also has better facilities like warehouses and vehicles that easily transport the rice between operators in the network. Large \wholesalers who buy very large quantities of rice from the importer is given credit facilities and are expected to reimburse between fourteen to twenty-one days [51].

The summary of the results of objective two is that the major rice importer is a very important stakeholder in the rice sub-sector in Sierra Leone. With Sierra Leone's high import penetration ratio which was about 66 percent in 2018 and the five rice importer account for about 70 percent of all rice imports, their influence in the sector cannot be ignored. Rice wholesalers are also a major part of the rice distribution network. They are the major link between the local and the imported rice distribution channels. However, there is a tendency for them to operate an oligopolistic system.

4.3 The Simulated Results of the Armington Partial Equilibrium Model

From the analysis in table 4.1 shows the calibrated parameters used in the model. The exogenously pre-defined parameters are introduced into the model. These parameters are the constant elasticity of transformation (CET) and the constant elasticity of substitution (CES). The endogenously calibrated parameters are parameters that are solved by the model. These parameters are the scale and share parameters of rice, maize, aromatic rice, and non-aromatic rice. The endogenously calibrated parameters are solved using a bench-mark or reference data and the exogenously pre-defined parameters. The bench-mark or reference data is a three-year average of quantities and prices of domestic rice, maize and imported rice from 2008 to 2010. From table 5.1, the scale parameter of the cultivation possibility function between rice and maize is low with a value of 0.002.

However, the scale parameter between aromatic and non-aromatic rice cultivation is higher with a value of 2.4. The scale parameters of the utility function are relatively high with values of approximately 2 for mix, rice, aromatic and non-aromatic rice.

level. Therefore, the changes obtained from the simulation are from normal or Marshallian demands.

***Trade Promotion**:* For simplification of the simulation, there is no tax discrimination between aromatic and non-aromatic rice. Equal shocks are applied to both tax rates simultaneously. From table 5.2, the decrease in tax on imported rice leads to a decrease in the volumes and value of domestically produced rice, an increase in rice imports and a mix effect on rice consumption. Rice cultivation will decrease from about 8.8 percent to 18.5 percent in value when total tax is reduced by 50 and 100 percent respectively. The greatest effect is observed from aromatic rice cultivation which decreases from about 9.7 percent to about 20.3 percent in value for a 50 and 100 percent tax decrease respectively.

Table 4.1 Calibrated Parameters

Parameters	*Mix*	*Rice*	*Aromatic rice*	*Non-Aromatic rice*
Exogenously pre-defined parameters				
CET between rice and maize (τ_{mix})	-1.1			
CET between aromatic and non-aromatic rice (τ_{rice})		-2.0		
CES between rice and maize (σ_{mix})	1.1			
CES between aromatic and non-aromatic rice (σ_{rice})		2.0		
CES between imported and domestic aromatic rice (σ_{aro})			3.0	
CES between imported and domestic non aromatic rice (σ_{naro})				3.0
Endogenously calibrated parameters				
Scale parameter of cultivation functions (A)	0.002	2.373		
Share parameter of cultivation functions (α)	0.882	0.706		
Transformation parameter of cultivation functions (β)	1.909	1.500		
Constant for relative supplies (K)	0.109	0.174		
Scale parameter of utility functions (B)	2.192	1.944	2.025	1.990
Share parameter of utility functions (σ)	0.533	0.402	0.424	0.457
Substitution parameter of utility functions (ρ)	-0.091	-1.500	-0.667	-0.667
Constant for relative consumptions (H)	1.153	0.450	0.398	0.600

Source: Author's Proposed Model Computation, 2020

4.4 Results from the simulation scenario of the Armington based partial equilibrium model

The simulations are performed by maximizing the aggregate utility function Cmix keeping total expenditure level E at its initial

As expected, maize cultivation will increase in volume because farmers shift from rice to maize cultivation. Maize cultivation will increase by 1.5, and 3.2 percent for a 50 and 100 percent decrease in tax respectively. However, maize cultivation in value will decrease by 0.3 and 0.8 percent for a 50 and 100 percent decrease in total tax respectively. This observation in volume and value of maize can be because as more maize is produced it will drive down maize prices and, hence, cultivation in value terms.

The decrease in taxes will have a greater effect on imports of non-aromatic than on aromatic rice. Total tax removal will lead to a 62.7 percent increase in the volume of non-aromatic rice while that of aromatic rice will increase by 54.8 percent. For consumption changes, the total consumption of rice and maize will increase. The total consumption of rice and maize will increase from 3.8 percent for a 50 percent decrease in tax to 8.8 percent for a 100 percent decrease in tax. It is interesting to note that rice and non-aromatic rice consumption will increase in both volume and value but aromatic rice consumption will increase in volume and decrease in value. This implies that the fall in aromatic rice price is greater than the increase in volume. Therefore, the value of aromatic rice consumption with tax removal is lower than the value with the tax.

percent respectively. Similarly, land devoted to rice will increase by 6.1, 12.2, and 24.4 percent respectively. For land size devoted to rice, the trend shows that a relatively greater portion of the land will go into aromatic than non- aromatic rice cultivation. For example, a 20 percent increase in land size will result in a 25.7 percent increase in rice land devoted to aromatic rice cultivation compared to 24.1 percent for non- aromatic rice cultivated. As expected, volumes and values of imported rice will decrease. The volume of imported aromatic rice will decrease by 8.4 percent and by 11.2 percent for non- aromatic rice as a result of a 20 percent increase in total land size. The total volume and value of rice and maize consumption and maize consumption will increase. However, the volume of rice consumption will increase but not its value. This is because the value of non-aromatic rice consumption decreases and since it has a greater share in total rice drives down the value of rice consumption. This results from the fact that the decrease in the price of non-aromatic rice is greater than the increase in the volume of non-aromatic after the land size is increased.

Table 4.2: Simulation Effects of Trade Promotion and Restriction on Cultivation, Imports and Consumption of Rice in Sierra Leone

Simulation scenario	*Parameter change*	*Crop type*	*Cultivation Changes (%)*		*Import Changes (%)*		*Consumption Changes (%)*	
			Volume	Value	Volume	Value	Volume	Value
Trade promotion								
		Mix	0.60	-3.09			3.80	
		Maize	1.48	-0.33			1.48	-0.33
50 % ↓ in total tax	**0.5*T**	Rice	-3.11	-8.75		8.01	8.87	0.31
		AR	-3.81	-9.74	22.80	6.22	7.85	-0.16
		NAR	-2.90	-8.46	25.73	8.75	9.24	0.48
		Mix	0.92	-4.77			6.14	
		Maize	2.31	-0.52			2.31	-0.52
75 % ↓ in total tax	**0.25*T**	Rice	-4.90	-13.48		12.36	14.45	0.50
		AR	-5.95	-14.91	37.35	9.53	12.78	-0.24
		NAR	-4.59	-13.05	42.38	13.54	15.05	0.76
		Mix	1.26	-6.55			8.84	
		Maize	3.21	-0.75			3.21	-0.75
100 % ↓ in total tax	**T=0**	Rice	-6.90	-18.47		16.99	21.07	0.70
		AR	-8.29	-20.30	54.80	12.99	18.62	-0.32
		NAR	-6.48	-17.93	62.56	18.65	21.96	1.07
Trade restriction								
		Mix	-0.06	0.29			-0.33	
		Maize	-0.14	0.03			-0.14	0.029
5 % ↑ in total tax	**1.05*T**	Rice	0.28	0.83		-0.75	-0.76	-0.027
		AR	0.35	0.93	-1.92	-0.60	-0.67	0.016
		NAR	0.26	0.80	-2.14	-0.82	-0.77	-0.043
		Mix	-0.11	0.58			-0.66	
		Maize	-0.27	0.06			-0.27	0.058
10 % ↑ in total tax	**1.1*T**	Rice	0.56	1.65		-1.50	-1.49	-0.054
		AR	0.69	1.86	3.78	-1.19	-1.32	0.032

Source: Author's Proposed Model Computation, 2020, ***AR = Aromatic Rice, NAR = Non-Aromatic Rice, ↑ = Increase, ↓ =Decrease***

4.4.1 Agricultural Land Expansion

Table 4.3 shows the simulated results of an increase in land size and productivity of the rice farmer. The results show that, more the land will be devoted to rice cultivation when total land cultivated is increased. Land devoted to maize will increase in size by 4.5, 8.9 and 17.8 percent when total land is increased by 5, 10 and 20

A 20 percent increase in land size will lead to an 8.3 percent increase in volume and a 0.6 percent decrease in the value of non-aromatic rice consumption.

Table 4.3: Simulation Effects of Expansion in Agricultural Land Size and Productivity on Cultivation, Imports and Consumption of Rice in Sierra Leone

Simulation scenario	*Parameter change*	*Crop type*	*Cultivation Changes (%)*		*Import Changes (%)*		*Consumption Changes (%)*	
			Volume	Value	Volume	Value	Volume	Value
Land expansion								
		Mix	4.78	1.06			3.75	
		Maize	4.48	0.11			4.48	0.11
		Rice	6.06	3.02		-2.75	2.17	-0.10
5 % ↑ in land size	**1.05*R**	AR	6.33	3.42	-2.18	-2.18	2.49	0.06
		NAR	5.98	2.90	-2.99	-2.99	2.05	-0.16
		Mix	9.56	2.08			7.49	
		Maize	8.94	0.20			8.94	0.20
10 % ↑ in land size	**1.1*R**							
		Rice	12.16	5.94		-5.39	4.34	-0.19
		AR	12.72	6.74	-4.30	-4.30	4.98	0.12
		NAR	11.99	5.70	-5.61	-5.85	4.11	-0.30
		Mix	19.07	4.01			14.92	
		Maize	17.79	0.38			17.79	0.38
20 % ↑ in land size	**1.2*R**	Rice	24.43	11.46		-10.39	8.70	-0.35
		AR	25.65	13.11	-8.35	-8.35	9.97	0.23
		NAR	24.06	10.96	-11.23	-11.23	8.24	-0.56
Increase in productivity								
		Mix	-0.25	1.01			0.38	
		Maize	-0.60	-0.14			-0.60	-0.14
5 % ↑ in productivity	**0.95*AR**	Rice	1.22	-3.38		-2.62	2.50	0.14
		AR	6.83	3.79	-2.03 -	-2.03	2.83	0.30
		NAR	6.47	3.26	-2.87	-2.87	2.37	0.08
		Mix	-0.52	2.09			0.82	
		Maize	-1.23	-0.30			-1.23	-0.30
10 % ↑ in productivity	**0.90*AR**	Rice	2.49	7.00		-5.43	5.27	0.28
		AR	14.51	7.89	-4.23	-4.23	5.97	0.62
		NAR	13.70	6.74	-5.92	-5.92	5.02	0.16
		Mix	-1.11	4.49			1.95	
		Maize	-2.61	-0.65			-2.61	-0.65
20 % ↑ in productivity	**0.80*AR**	Rice	5.17	15.06		-11.65	11.87	0.61
		AR	33.04	17.13	-9.22	-9.22	13.44	1.32
		NAR	30.99	14.43	-12.67	-12.67	11.30	0.36

Source: Author's Proposed Model Computation, 2020, ***AR = Aromatic Rice, NAR = Non-Aromatic Rice, ↑ = Increase***

4.4.2 Increase in Rice Productivity

An increase in productivity implies that to obtain the same level of output, less of the current scale or efficiency parameter is required. This explains why the scale or efficiency parameter of rice is reduced although the effect of an increase in productivity is being simulated. The results obtained from the simulation conform to theory. An increase in rice productivity implies that more rice will be cultivated and resources will be shifted from maize to rice cultivation. Consequently, less maize will be produced. For example, a 20 percent increase in rice productivity leads to a 5.17 percent increase in the volume of rice and a decrease of 2.6 percent for maize. However, the absolute effect on maize is stronger and therefore, the total cultivation of rice and maize decreased by 1.1 percent. The importation of rice also decreases in volume and value. Imports of aromatic rice decrease by 9.2 percent and imports of non-aromatic rice also decrease by 12.7 percent in volume for a 20 percent increase in productivity. Total consumption also increases by 2.0 percent. For a 20 percent increase in rice productivity, the consumption of rice increases by 11.9 percent constituting 13.4 percent for aromatic rice consumption and 11.3 percent for non-aromatic rice consumption.

4.5 Fall and Rise in the World Rice Prices

Fall in World Rice Prices: Table 5.4 shows the simulated results of world rice prices on cultivation, imports and consumption of rice. For simplification of the simulation, equal shocks are applied to both the CIF price for imported aromatic rice ($PCIF_{aro}$) and the CIF price for imported non aromatic rice

Table 4.4: Simulation Results of World Rice Prices on Cultivation, Imports and Consumption of Rice in Sierra Leone

Simulation scenario	***Parameter change***	***Crop type***	***Cultivation Changes (%)***		***Import Changes (%)***		***Consumption Changes (%)***	
			Volume	Value	Volume	Value	Volume	Value
Favorable conditions								
		Mix	0.21	-1.10			1.30	
5 % ↓in world rice	$0.95*PCIF_{aro}$	Maize	0.52	-0.11			0.52	-0.11
prices	and	Rice	-1.08	-3.14		2.86	2.99	0.11
	$0.95*PCIF_{naro}$	AR	-1.34	-3.52	7.63	2.25	2.65	-0.06
		NAR	-1.00	-3.02	8.55	3.12	3.11	0.17
		Mix	0.44	-2.25			2.73	
10 % ↓ in world rice	$0.95*PCIF_{aro}$	Maize	1.08	-0.24			1.08	-0.24
prices	and	Rice	-2.24	-6.39		5.84	6.31	0.22
	$0.95*PCIF_{naro}$	AR	-2.76	-7.14	16.18	4.56	5.59	-0.12
		NAR	-2.09	-6.17	18.20	6.38	6.57	0.35
		Mix	0.91	-4.70			6.04	
20 % ↓ in world rice	$0.8*PCIF_{aro}$	Maize	2.28	-0.52			2.28	-0.52
prices	and	Rice	-4.83	-13.30		12.19	14.22	0.49
	$0.8*PCIF_{naro}$	AR	-5.87	-14.71	-36.76	9.41	12.58	0.24
		NAR	-4.52	-12.88	41.69	13.36	14.81	0.75
Worsening conditions								
		Mix	-0.21	1.06			-1.19	
5 % ↑ in world rice	$1.05*PCIF_{aro}$	Maize	-0.50	0.11			-0.50	0.11
prices	and	Rice	1.01	3.02		-2.75	-2.70	-0.10
	$1.05*PCIF_{naro}$	AR	1.27	3.42	-6.84	-2.18	-2.39	0.06
		NAR	0.93	02.90	-7.61	-2.99	-2.81	-0.16
		Mix	-0.40	2.08			-2.28	
15 % ↑ in world rice	$1.1*PCIF_{aro}$	Maize	-0.97	0.20			-0.97	0.20
prices	and	Rice	1.96	5.937		-5.39	5.14	-0.19
	$1.1*PCIF_{naro}$	AR	2.48	6.74	-13.00	-4.30	-4.56	0.12
		NAR	1.81	5.70	-14.41	-5.85	-5.35	-0.30
		Mix	-0.78	4.01			-4.23	
20 % ↑ in world rice	$1.2*PCIF_{aro}$	Maize	-1.84	0.38			-1.84	0.38
prices		Rice	3.69	11.46		-10.4	-9.42	-0.35
	and	AR	4.71	13.11	-23.62	-8.35	-8.35	0.23
	$1.2*PCIF_{naro}$	NAR	3.38	10.96	-26.03	-11.2	-9.80	-0.56

Source: Author's Proposed Model Computation, 2020, ***AR = Aromatic Rice, NAR = Non-Aromatic Rice, ↑ = Increase,*** ↓ Decrease

($PCIF_{naro}$) simultaneously. Favorable conditions implies fall in world rice prices and this is reflected in the CIF prices of imported rice. When world prices fall, domestic rice cultivation falls in both volume and value, imports increase in both volume and value, and consumption of rice increases in volume and value. However, the disaggregation of rice shows an increase in volume of aromatic rice consumption but a decrease in value of aromatic rice consumption whiles non aromatic rice consumption shows both an increase in volume and value. For example, a 20 percent decrease in world rice prices will results in 2.3 percent increase in maize cultivation. Domestic rice cultivation will decrease by 4.8 percent. Aromatic rice cultivation will decrease by 5.9 percent and non-aromatic rice will decrease by 4.5 percent. A 20 percent decrease in world rice prices will also lead to a 36.8 percent increase in volume of aromatic rice imports and a 41.7 percent in volume of non-aromatic rice imports. Overall, total consumption of rice and maize will increase by 6.0 percent. Total rice consumption will increase by 14.2 percent whiles aromatic rice consumption will increase by 12.6 percent and that of non-aromatic rice consumption will increase by 14.8 percent.

***Rise in World Rice Prices*:** From table 4.4, for worsening world rice prices, the CIF prices of imported rice are increased by 5, 10 and 20 percent. The results show that maize cultivation will decrease and rice cultivation will increase in volume but both rice and maize cultivation will increase in value. Also, rice imports will decrease in both volume and value. Total consumption of rice and maize and consumption of maize, rice, aromatic and non-aromatic rice will all decrease in volume. For example, a 20 percent increase in world rice prices will result in a 1.8 percent decrease in volume of maize cultivation and a 3.7 percent increase in volume of rice cultivation. Aromatic rice cultivation will increase by 4.7 percent whiles that of non-aromatic rice will increase by 3.4 percent. For imports, aromatic rice will decrease by 23.6 percent and non-aromatic rice will also decrease by 26.0 percent. For consumption, total consumption of rice and maize decreased by 4.23 percent. Consumption of maize, rice, aromatic rice and non-aromatic rice will all decrease by 1.2, 9.4, 8.4 and 9.8 percent in volumes respectively. The summary of the simulation effects shows that trade liberalization through the removal of taxes on rice imports leads to increase in volume of total consumption of rice and maize.

However, a trade restriction with the objective of promoting or protecting the local rice farmer may lead to marginal increase in rice cultivation but will ultimately lead to a decline in volume of total consumption of rice and maize. Both land expansion and increase in rice productivity will lead to increase in total consumption of rice and maize. The summary of the world rice conditions is that total consumption of rice and maize and consumption of both rice and maize consumption will increase when world market prices fall. On the other hand, a worsening world market condition will translate into a decrease in volume of total consumption of rice and maize and consumption of both rice and maize. Government can intervene by having a buffer stock system or enter into a public-private partnership (PPP) to establish a buffer stock system. Then it will be possible to have stable consumption for consumers when world market prices rise and when world market prices fall very low, to have stable incomes for local rice farmers because they will be insured against the very low prices.

V. Conclusion

The first objective of this study is to analyze the development of Sierra Leone's rice sub-sector through trend analysis of cultivation levels, acreage under cultivation, and yield per hectare and rice import penetration ratio from 2000 to 2018. The results from the study show that the annual growth rate in rice cultivation has to be about 5.8 percent. The dip in cultivation in 2018 on the back of an impressive upward trajectory from 2008 can be attributed to the government's reduced budget allocation to the agriculture sector as a whole. Acreage cultivated also increased annually by 5 percent and yield also increased abysmally by 0.8 percent a year. The rice import penetration ratio in 2018 was about 66 percent. It can, therefore, be deduced from these facts that although Sierra Leone's rice cultivation is increasing, the country still depends heavily on imported rice to augment its domestic supply.

The second objective of the study is to analyze the rice distribution network and identify the opportunities to shift to rice varieties demanded by consumers. The conclusion of the analysis of the rice distribution network is that there are two main rice distribution channels in Sierra Leone: the local rice channel and the imported rice channel that are barely interlinked. The imported rice channel is shorter and more efficient than the local rice channel. In the imported rice channel, the major rice importer is the most influential actor in the network and the rice wholesalers are the most influential actors in the local rice channel. The conclusion of the identification of opportunities for farmers to the shift to rice varieties demanded by consumers is that from the existing distribution network, there is no link between the rice producers and the rice importer. Therefore, an opportunity that arises is, considering the high capital base of the major rice importer: the rice importer can enter into some form of agreement or contract with the smallholder farmers to produce rice varieties that the rice importer wants. When the farmers are organized into farmer-based organizations (FBOs), the rice importer can provide them with the seeds of the rice varieties that consumers want and also provide the farmers with other inputs. With guaranteed markets for their produce, the farmers will be motivated to cultivate these varieties. The rice importer can then buy the paddy rice from the farmers and mill the rice to high standards and sell it through the imported rice distribution channel.

The third objective of this study is to identify different scenarios of agricultural and trade policies that could affect cultivation, consumption and imported quantities of rice using an Armington based partial equilibrium simulation model. The simulation results show that the total removal of current taxes on imported rice will lead to a 3.2 percent increase in maize cultivation whiles aromatic and non-aromatic rice cultivation will decrease by 8.3 and 6.5 percent respectively. Imports of aromatic and non-aromatic rice will increase by 54.8 and 62.6 percent respectively. Overall rice consumption will increase by 21.1 percent. A 20 percent increase in taxes will result in total rice consumption decreasing by 2.9 percent. When agricultural land is expanded by 20 percent, rice cultivation will increase by 24.4 percent and consumption will increase by 8.7 percent. A 20 percent increase in rice productivity will lead to a 5.2 percent increase in rice cultivation and an 11.9 percent increase in rice consumption. A 20 percent decrease in world rice prices will lead to a 4.8 percent decrease in cultivation and a 14.2 percent increase in consumption. For a 20 percent increase in world rice prices, rice cultivation will increase by 3.7percent and consumption will decrease by 9.4 percent.

Recommendations

The first recommendation has to do with the general improvement of the infrastructure especially in the local rice distribution channel. As a result of the high transaction costs due to bad roads. Involved in moving goods from rural areas to urban markets, most individuals do not want to engage in the rice business. This leaves the market for a few rice buyers (market women) who exploit the situation by paying rice farmers below the market price. As part of government policy to improve the rice sub-sector, conscious efforts should be made to repair bad roads and construct new ones to open up rice farming communities to markets and thereby reducing the high transaction cost which will reflect in the final price of rice on the market. The opening up of farming communities to markets also has the tendency to break down the oligopolistic structure that exist between the market women and the smallholder rice farmers because more people will be engaged in the sector and this will increase the competition in the market.

From the simulation scenarios, a 20 percent increase in taxes, land size and rice productivity will lead to a 1.09, 24.43 and 5.17 percent increase in rice cultivation respectively. Thus, a holistic approach to simulate growth in the local rice sub-sector in Sierra Leone is needed. Therefore, it is recommended that land expansion and trade liberalization should be promoted in the short run. Since it takes time to develop improved seeds and change old agronomic practices, improving rice farmers' productivity should be a short, medium to long term goal. Also, when total land size is increased, land devoted to aromatic rice cultivation will increase. Land devoted to aromatic rice cultivation will increase by 25.7 percent and that of non-aromatic rice will be 24.1percent. This is good for the local rice sector because of the growing trend by consumers for aromatic rice.

With the current level of rice productivity, a quantum leap is needed for increased productivity to make the needed impact on rice cultivation levels. With commodity Agro Investment as models who entered the rice sector with improved technology, there is still the opportunity for large scale rice farmers to be encouraged to enter the sector. With their higher levels of technology and high yielding varieties, a 20 percent increase in productivity will have a greater impact on rice cultivation than the current 5.17 percent. Therefore, it is recommended that government policy should be geared towards encouraging large scale farmers to enter the rice sub-sector whiles government continues to improve the productivity of the smallholder rice farmers.

Acknowledgment

The authors wish to thank the Ministry of Agriculture, Forestry and Food Security (MAFFS) and Food and Agricultural Organization (FAO) for supporting us with information and dataset to conduct this study. We also thank the Almighty God for keeping us strong and providing us with requite knowledge during the research process.

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