TREND, FORECAST AND SUPPLY RESPONSE OF CASSAVA PRODUCTION IN NIGERIA (1961 TO 2014)

BY

SALIHU, Abu Garba

(PhD/SAAT/2014/605)

DEPARTMENT OF AGRICULTURAL ECONOMICS AND FARM MANAGEMENT

SCHOOL OF AGRICULTURE AND AGRICULTURAL TECHNOLOGY

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

MARCH, 2021

ABSTRACT

Cassava is one of the most important staple foods in Nigeria, simulation of models that will increase the production of cassava is very necessary. The study was conducted to estimate trend, forecast and supply response of cassava production in Nigeria. Secondary data covering the period of 1961 to 2014 were used for the study. Secondary data used include prices, yield, output and hectarage of Cassava. Other data include rainfall, number of rain days, date of onset and cessation of rain, temperature and relative humidity. The data was obtained from Food and Agricultural Organization (F.A.O.), International Institutes of Tropical Agriculture (I.I.T.A.), Nigeria Bureau of Statistics (N.B.S.) and Nigeria Meteorological Agency. To achieve the aim of the study, four techniques were employed to analyse the data. The techniques were growth rate, grafted technique, partial adjustment hypothesis and adaptive expectation hypothesis. Simulations were also carried out to show the effect of some macro-level policy (pre-SAP, SAP, post-SAP and A.T.A. periods) changes on cassava production. The entire periods under study shows an encouraging result on the hectarage, yield and output with growth rates of 4.1%, 0.1% and 4.2% respectively. The result of the study also revealed that polynomial spline models were adjudged to be the best forecasting model among other models like linear, semi-log and growth models. The study also forecast hectarage, yield and output of cassava from 2015 to 2035. The results show that by the year 2035, the hectarage to be cultivated will be 11,200,000 hectares, yield will be 98,000kg/ha and output will also be 11,000,000 tonnes. The result revealed that the mean of the partial adjustment coefficient of the farmers was 4.69E-07 while adaptive expectation coefficient was -0. 256186542 indicating that less error were committed in making hectarage decisions than in forming price expectation. The results of elasticity of supply were relatively inelastic both at the short run and long run. The short run and log run elasticities were -8.41E-15 and -2.74E-08 respectively for the partial adjustment hypothesis and -3.97E-02 for short run and 0.217803916 for long run under adaptive expectation hypothesis, this shows that farmers' response to price have not been encouraging. The conclusion shows that there was an increase in the growth rate of cassava production in Nigeria from 1961 to 2014, the findings also shows that spline models were best fit in forecasting cassava production in Nigeria. Cassava farmers are less responsive to change in price and economic incentives. The recommendations, thus, there is the need to establish the short term and long term cassava needs base on present population rate of growth and employ the models estimated to establish hectarage, yield and output that will provide this need. The estimated elasticities of cassava supply are useful guide in studying the responsiveness of the farmers especially with regards to price and can be used in studies where such an estimate is required. Government should reintroduce minimum and maximum pricing policy with enough resources to guard it. Technology in farming has the tendency in increasing output; therefore, Government and private sector should train farmers on modern technology of farming.

TABLE OF CONTENTS

CONTENTS **Pages**

List of Tables

Tables

Pages

List of Figures

Figures

Pages

List of Appendix

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Many development oriented policies have been implemented in Nigeria, especially in the agricultural sector since independence. The Federal Government has made some institutional and policy reforms targeted at improving the socio-economic status of the farmers in Nigeria. These include Agricultural Credit Guarantee Scheme Fund (ACGSF), River Basin Development Authorities (RBDAs), Agricultural Development Programmes (ADP) and the Cassava Multiplication Programme (CMP) and the School to Land Programme, (Iyagba and Anyanwu, 2012). The Root and Tuber Expansion Programme (RTEP) is an offshoot of the CMP. Eke-okoro and Njoku, (2012), contended that RTEP is a farmer oriented programme whose beneficiaries are poor households and smallholder farmers but the overall objective of RTEP is to enhance national food self-sufficiency, improve rural households' food security and income for poor farmers within the cassava producing States of Nigeria, (Iyagba and Anyanwu, 2012).

Cassava is an important source of dietary carbohydrate, and provides food for over 60 million in Nigeria, (Abdulahi, 2003). Cassava's adaptability to relatively marginal soils, erratic rainfall; its high productivity per unit of land and labour, the certainty of obtaining some yield even under the most adverse conditions and the possibility of maintaining continuity of supply throughout the year (Nweke, 1994), make this root crop a basic component of the farming system in many areas of Nigeria. Famine rarely occurs in areas where cassava is widely grown, since it provides a stable food base to the food production system (Iyagba and Anyanwu, 2012). Apart from its use as a staple food to human beings, other uses include animal feed formulation, agro-industrial uses (e.g. starch, ethanol, adhesive, fructose/glucose syrup), the peels in organo-mineral fertilizers formulation (Iyagba, 2010).

Nigeria was a major cassava producing country ranking fourth in the World after Brazil, Zaire and Indonesia in the 18^{th} Century and later part of the 19^{th} Century, Central Bank of Nigeria, (CBN, 2005). However, today, Nigeria is the largest producer of cassava in the World with an annual estimate of 54.8 million metric tons, 7.1 million hectares cultivated and yield of 77,203 kg/ha, (Food and Agricultural Organisation Statistical Database (FAOSTAT, 2015). The country has consistently been ranked as the world's largest producer of cassava since 2005, (FAO, 2012).

Presidential Initiative on Cassava launched in 2003 brought cassava and its potentials to the national limelight. The Initiative has a goal of promoting cassava as a viable foreign exchange earner for Nigeria, and also development of the cassava production system in order to sustain the national demand. Another recent government action on cassava production was the federal government Agricultural Transformation Agenda (ATA). The transformation focuses on cassava value chain with the production of High Quality of Cassava Flour (HQCF) and making it mandatory for the replacement of up to 10% wheat flour in bread with cassava, (Asanke-pok, 2013). As part of its effort in developing a vibrant cassava market locally and internationally, government designed cassava master plan in 2005 thereby encouraging large production cassava in the country.

1.2 Statement of the research problem

Cassava production and processing has been on the increase and Nigeria is the largest cassava producing country in the world with estimated annual production of 54.8 million tonnes, (FAOSTAT, 2015), there was still a large gap to be filled in meeting the food and raw materials needs of the country in terms of products and by products. In addition, according to Akinpelu, (2011) and International Institutes for Tropical Agricultue, (2007), over 90 percent of the country's cassava is consumed locally as food, and very little is left for industrial processing and less than 1% of cassava in Nigeria is processed for industrial purposes.

Producers' decision behavior could be approximated by the amount of effort they are willing to put into the production process, the size of the area worked could be proxy for their expected output rather than the actual harvest in defining a response to economic incentives. The starting point in the modeling is the selection of either the amount of production or the size of the cultivated area as the dependent variable. To measure the responsiveness exactly would require highly detailed disaggregated cost data that typically unavailable. To circumvent the data problem, it requires the simulation of the model which involves a very long process and fully specified formulation.

In order have accurate prediction about the estimation of the future production of cassava, the data must linearly relate to the series over the entire period, unfortunately, time series might not be linearly related to the series over the entire sample period, as the model tends to suggest. The models have to be improved upon by dividing the data into different segments and applying different functional forms as suggested by the data rather than forcing the data to accept a particular form. The whole process is very tedious that requires careful and systematic approach otherwise wrong prediction might results.

The Nerlovian approach used Ordinary Least Square (OLS) to estimate the specification of the supply response of cassava farmers. This means that the estimates of agricultural supply response are based on the assumption that the underlying data process is stationary. Agricultural time series tend to be non-stationary, that is, their two moments, means and variance are not constant. Using OLS with non-stationary variables may result in spurious regression. To ensure stationary variables, the equation has to be reformulated in terms of difference, but this losses important information conveyed by the levels, such as information on long run elasticities.

However, to be able to simulate models that will provide solutions to the identified problems, certain pertinent questions needed to be asked. Such questions include:

i. what has been the trends of cassava hectarage, yield and output in Nigeria from 1961 to 2014 ?

ii how will grafted response models estimate cassava hectarage, yield and output in Nigeria from 1961 to 2014 ?

iii, what will be the future of cassava hectarage, yield and output in Nigeria from 2015 to 2035?

iv. How do farmers form expectation about future prospects in price changes and adjust production to policy changes that affect cassava production using Nerlove model, and what is the magnitude of expectation and adjustment?

v. What will be the future of cassava supply in Nigeria using estimated adaptive expectation and partial adjustment models?

vi. What has been the short run and long run price elasticity of cassava from 1961 to 2014?

1.3 Aim and objectives

The aim of the study was to analyse the trend, forecast and supply response of cassava production in Nigeria from 1961 to 2014).

The specific objectives of the study were to:

i. examine the trend of cassava hectarage, yield and output from 1961 to 2014,

ii. estimate models through grafted response for cassava hectarage, yield and output from 1961 to 2014,

iii. forecast cassava hectarage, yield and output from 2015 to 2035,

iv estimate Nerlovian adaptive expectation and partial adjustment models for cassava supply in Nigeria incorporating additional weather variables,

v forecast cassava supply from 2015 to 2064 using estimated adaptive expectation and partial adjustment models and

vi estimate short run and long run elasticities of supply for cassava in Nigeria from 1961 to 2014.

1.4 Hypotheses

The following hypotheses were tested:

1. H_O: Adaptive expectation and partial adjustment coefficients of cassava supply response in Nigeria do not vary from year to year but remain the same through the entire series.

2. H_O: Short-run and long run elasticities of cassava supply response in Nigeria do not vary from year to year but remain the same through the entire series.

1.5 Justification of the Study

Cassava's adaptability to relatively marginal soils, erratic rainfall; its high productivity per unit of land and labour, the certainty of obtaining some yield even under the most adverse conditions, need greater attention that have not been given in the past. As such, the need arises for models that predict and forecast future production of adequate quantity of cassava for Nigeria's teeming population which can also provide policy direction to both government and private sector.

In this study, an attempt was made to contribute to general knowledge of supply responsiveness in agricultural production in Nigeria and Cassava production in particular, thereby providing basis for concerted government action towards effective commercialization of Cassava production in the country. The study would provide models for predicting and forecasting the volume of output and other variables with a view to making them available to policy makers. The study will also provide analytical framework for the study of farmers' behaviour and expectation formation in relation to Cassava supply in Nigeria and provide basis for further econometric research into Cassava production.

The gap in knowledge filled by this research is the introduction of four joint points in forecasting hectarage, yield and output of cassava in Nigeria, which is different from the universal three joint points and the modification of Nerlove model to capture the effects of temperature on the supply of cassava in Nigeria.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The Cassava Tuber Crop

2.1.1 Origin and Diversification of Cassava

Cassava originated from tropical America and was first introduced into Africa in the Congo basin by the Portuguese around 1558, (Tesfaye *et al.* 2013)). Early site sand farms of cassava existed in Northern Brazil and Central America but its greatest staple status is in tropical Africa (CIAT 1993). It is from these sites that cassava was introduced into other parts of the World including Africa, during the early trade movements and explorations by the Portuguese.

Cassava was introduced into Nigeria by the Portuguese traders and explorers from Fernando-Po to Warri in the then Mid-Western Nigeria in the late 18^{th}Century (Eke-okoro and Njoku, 2012). It later spread to Lagos, Badagry, Abeokuta and Ijebu in the early 19^{th}Century by slaves returning from West Indies and Sierre Leone who settled in these towns (Eke-okoro and Njoku, 2012). These returnees processed cassava into gari, lafun and iwa-panya (roast and eat) for food. Cassava and cassava products were later introduced into Eastern Nigeria along the Coast towns of Calabar and Yenagoa by traders from Western Nigeria. Thus, cassava may have been introduced in Nigeria to different regions about 330 years ago (Eke-okoro. and Njoku, 2012).

2.1.2 Cassava development in Nigeria

Cassava development in Nigeria consists of multi-dimensional set of activities fashioned by Research Institutes, Government and its policies like Agricultural Development Agencies, Funding Agencies, Farmers and Non-Governmental Organizations (NGOs). Cassava development in Nigeria is basically embarked upon by both national and international bodies, ministries and agencies. Basically, there are four stages or periods of cassava development in Nigeria namely: the incipient cassava development period stretching from 1940 to 1953; medieval cassava development period stretching from1970 to 1990 and the pre-emptive - CMD cassava development period stretching from 1995 to date (Eke-okoro and Njoku, 2012). These developmental stages or periods in Nigeria are fully discussed below.

i. The incipient cassava development period (1940-1953)

Cassava improvement and development started in 1940 with collection and introduction of superior germplasm for improved yields and resistance against cassava mosaic virus (Umunah, 1977). Based on a two-year selection of the collected germplasm, the first cassava hybrid called Gold Coast Hybrid (GCH 7) or 37065 emerged in 1942. This variety had an average yield of 9 tonnes/ha with an improvement of 28% in yield over local varieties. Further selection of locally available cassava germplasm in 1953 gave rise to another superior cassava hybrid popularly called Oloronto or 53101. This was recommended to farmers in Southwestern Nigeria.

ii. Medieval cassava development period (1954-1967)

The medieval cassava development period is a period of modern cassava research and development in Nigeria. In 1954/55, modern cassava research and development started at the Federal Department of Agricultural Research (FDAR), Moor Plantation, Ibadan, when a Plant Breeder was assigned to the cassava improvement programme. With the provision of a breeder, more collections were made locally and from foreign countries. Some of the germplasm acquired from foreign countries include *Manihot glaziovii* from Puento Rico; *Manihot melonohasis* and *Manihot saxicola* from Surinam; 58308; 58; 98 and 58212 from Amani in EastAfrica. Crosses of these cassava varieties 53101 and 42074 e.t.c led to the development and release of cassava hybrids such as 60444, 60:06 and 60447 in 1967 (Eke-okoro, 2012).

iii. National and international collaborative cassava development period (1970- 2010)

The national and international collaborative cassava development period is a period when National and International Research Institutions became actively involved in cassava improvement and development in Nigeria. This era coincided with a period when a virulent cassava disease called cassava bacterial blight (CBB) was a scourge on cassava in Nigeria. This was in 1972 and only cassava variety, 60506 and few other varieties withstood this virulent cassava disease. Breeding work at International Institute of Tropical agriculture (IITA), Ibadan started later in 1976. They released the first two cassava hybrids- TMS 30211 and TMS 30395 that assisted in controlling the virulent cassava bacterial blight disease. Shortly, IITA flooded the Nigerian cassava industry with more cassava hybrids TMS 30572, TMS 30001, TMS 300017, TMS30110, TMS 30337, TMS 30555, and TMS 4(2)1425 (IITA 1984). These cassava hybrids were high yielding and resistant to Cassava Mosaic Virus Disease (CMD), Cassava Bacterial Blight (CBB), Cassava Anthracnose Disease (CAD), Cassava Mealybug (CMB) and Cassava Green Mite (Akoroda *et al*., 1985).

In its contribution to fight the virulent cassava bacterial blight disease ravaging cassava in Nigeria, the National Root Crops Research Institute, Umudike, shortly after 1976 released some resistant and high yielding cassava varieties namely: -NR 41044, NR 8082, NR 8083,NR 8212, NR 8267 and NR 8233 etc. In order to reduce the fear of cyanide poison pre-empted by cassava consumers, IITA, Ibadan, developed some high yielding and low cyanide cassava varieties notably - TMS 4(2)1425, TMS30001. The National Root Crops Research

Institute, Umudike, in the late 1980 also developed five low cyanide cassava varieties (Sweet cassava varieties) namely: NR84175, NR 84292, NR 84104, NR 8959 and NR 8421. (Eke-okoro, 2012).

iv. Pre-emptive - CMD cassava development period (1995-Date)

The pre-emptive - CMD cassava development period is a period when cassava improvement and development focused on resolving the negative production pressures of a new strain of cassava mosaic virus from east Africa pre-empted to infest Nigeria cassava farms in future. The cassava breeding programme of the International Institute of Tropical Agriculture, later in 2005 in collaboration with the National Root Crops Research Institute (NRCRI), Umudike, released five new cassava varieties namely: -TME 419, TMS 97/2205 TMS 98/0505;TMS 98/0581 and TMS 98/0510 with a view to checking this new strain of virus. These varieties have an average yield between 35-45t/ha, 15-20% starch content, 30-35% dry matter and resistant to cassava mosaic virus disease of all the virus strains (Table 2.1).

Thus, from the incipient cassava development period to the recent pre-emptive (CMD) cassava development era, more than thirty cassava varieties have been developed and injected into the Nigerian farming systems. The availability of these improved cassava varieties have led to high trend of yield increase in our farms.

Table 2.1: Pre-emptive CMD Cassava Varieties

S/no	Variety	Mean Yield tone/ha	Dry Matter %	Starch %	Protein %
1	TME 419	35 - 40	30 – 35	15 – 20	1.9 – 2.8
2	TMS 97/2205	25 – 29	30 – 41	60 – 74	1.2 – 4.2
3	TMS 98/0505	21 – 37	25 – 41	62 – 75	2.3 – 5.7
4	TMS 98/0581	20 – 31	29 – 40	60 – 75	2.2 – 4.5

5	TMS 98/0510	13 – 27	20 – 33	66 – 74	2.6 – 4.6

Source: Annual report, NRCRI, 2005

v. Nationally coordinated research programme (NCRP) on cassava (1996- date)

In July 1996, Nationally Co-ordinated Research Programme (NCRP) was approved for cassava. Earlier, national programmes such as Priority Research Projects (PRP) and National Agricultural Research project (NARP), dove-tailed into NCRP. The NCRPs constitute a step in the implementation of the Medium Term Research Plan (MTRM) of the National Agricultural Research Strategy Plan (NARSP) (1996 - 2010). Under NCRP well-focused research programmes on roots and tubers crops are collectively planned and executed by NRCRI, other National Research Institutes, Universities, Institute of Agricultural research (IARs), International institute of Tropical Agriculture (IITA), Agricultural development programs (ADPs), NGOs and farmers. Some of the research themes and achievement of NCRP on cassava are as follows:

a) Selection of improved cassava varieties frontier cropping and resistance to major pests and diseases.

b) Evolving integrated pest and diseases management practices for cassava pests and diseases.

c) On-farm validation of existing technology for small scale storage of cassava tubers.

d) Training of extension agents and selected farmers in the art of rapid multiplication of cassava.

e) Determination of techniques for preserving cassava stems for storage.

f) Determination of fertilizer requirements in cassava mixed cropping systems and so on.

The major achievements in technology development under NCRP include:

a) Improved production technologies leading to increased national output of cassava from 23.3 million tons/annum in 1994 to 45.6 million tons/annum in 2010.

b) Development of low cyanide as well as high yielding, pest and disease resistant, cassava varieties.

c) Selection of high yielding, pest and disease resistant cassava varieties that is also suitable for intercropping.

d) Development of a cassava hand peeling tools for peeling of cassava.

e) Integrated control measures for control of cassava mosaic disease, (ACMD), cassava bacterial blight (CBB) and cassava green mite (CGM) were developed and documented. NRCP for cassava and yam are still implemented until date in Nigeria.

2.1.3 Synergistic components of cassava development in Nigeria

Cassava improvement programmes stimulated advancement in research on the best agronomic/cultural practices for optimum production, cassava health management techniques to tackle negative biotic and abiotic stresses that limit production. Others are micro propagation by Tissue culture; Bio-control measures; processing technologies; application of molecular marker assisted breeding to dictate promising lines early inbreeding cycles and farm management. These research components contributed in several measures towards cassava development in Nigeria. Nigeria was a major cassava producing country ranking fourth in the World after Brazil, Zaire and Indonesia in the 18th Century and later part of the 19thCentury (CBN, 2005). However, today, Nigeria is the largest producer of cassava in the World with an annual estimate of 54.8 million metric tons, with 7.1 million hectares cultivated, (FAOSTAT, 2015). This is as a result of advances in cassava improvement and development which gave rise to improved varieties that are high yielding and resistant to cassava pests and diseases.

2.1.4 Salient Factors that Contributed to Cassava Development in Nigeria

Eke-okoro and Njoku, (2012), enumerated some salient factors that contributed in several measures to the success history of cassava development in Nigeria. These factors are enumerated below.

i. Government and government policy

The contribution of succeeding Governments in Nigeria and her policies is of great importance in cassava development in Nigeria. Between 1960 and 1970, most agricultural policies were directed towards export of crops (ground nut, cocoa, rubber, oil palm etc) However, from 1975 to the present time, most governments in Nigeria have decided as a matter of policy to promote and reinforce research and development in cassava improvement and production. This singular policy of the Government has led to diversification of cassava products into diverse food forms that were not in existence in the last two centuries in Nigeria. The Government policy on food security, food self-sufficiency and diversification of the economy has encouraged agricultural policy makers to reinforce cassava development in Nigeria. The recent presidential initiative on cassava development and export is a policy made to encourage cassava improvement in Nigeria.

ii. Financial agencies

National and International Financial Agencies and Organizations such as Food and Agriculture Organization (FAO), United States Agency for International Development (USAID), Deutsche Gesellschaft Fuer Technische Zusammenarcheit (GTZ), International Fund for Agricultural Development (IFAD), United National Development Programme (UNDP), Generation Challenge Programme (GCP) of CGIAR and Counter-part Funds of

Federal and State Government, have provided the enabling financial backing which stimulated the development of many cassava varieties in Nigeria.

iii. Research collaboration

The initiation of research collaboration between national, regional and international research Institutions tremendously contributed to cassava development in Nigeria. Following the devastating effect of cassava bacterial blight in 1972 and the current devastating effect of new strain of mosaic virus ravaging cassava in the continent (Africa), which was detected by IITA, Ibadan, the Federal Government of Nigeria decided to reinforce research collaboration between IITA and NRCRI through the policy of the presidential initiative on cassava. This initiative led to the development and release of five new cassava varieties to check-mate the recent virulent mosaic virus strain that is ravaging cassava in Africa.

iv. Production of research manuals, extension guides and information

The exchange of information, extension services and production of training manuals such as the current manual on cassava stem and root production produced by the National Root Crops Research Institute, Umudike, (Eke-Okoro *et al*., 2005) provided information and practical knowledge thereby encouraging cassava development in Nigeria. The publication of Extension guide on cassava in Nigeria by NRCRI is a useful tool for disseminating information among scientists, farmers and donor agencies. The recent training of Nigerian farmers, local women and men on production of value added products of cassava embarked by NRCRI, is another milestone - capacity building for cassava development in Nigeria. The recent improvement of cassava varieties of diverse architecture and wide adaptation encouraged further cultivation of cassava in areas traditionally do not produce cassava. Cassava can now be grown in an ''unfavorable'' environment of Yobe and Borno States of Nigeria. This development has brought cassava cultivation to about 28 States of Nigeria, thereby stimulating expansion in cassava cultivation in Nigeria.

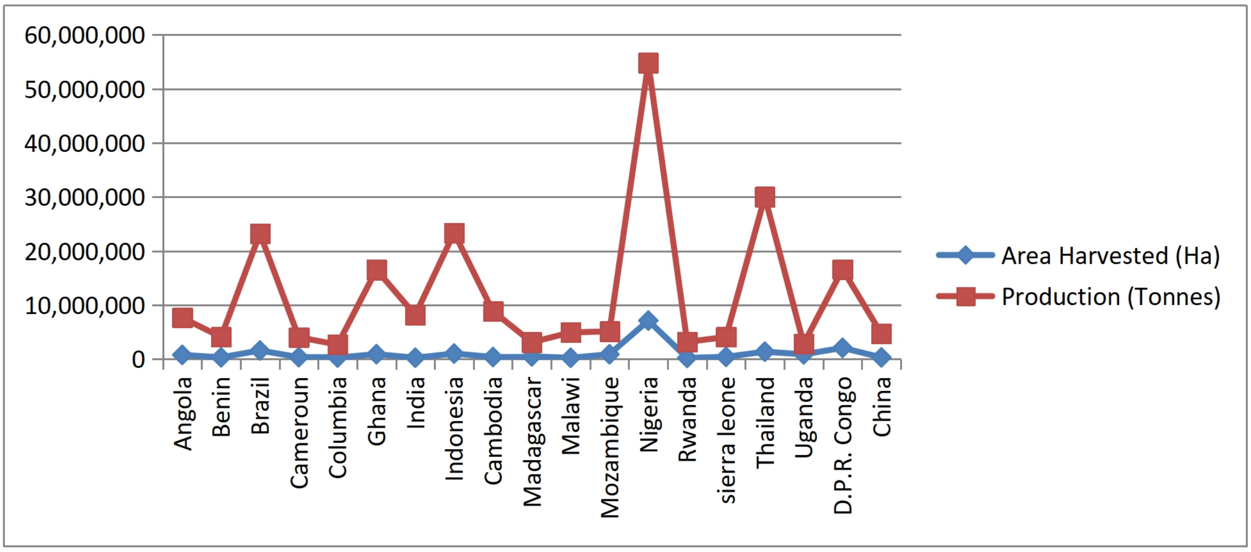
2.1.5 Cassava Consumption and Utilization

In Africa, cassava is an important staple crop particularly in the more tropical countries as the crop has a high potential of feeding rapidly increasing population and is generally more affordable if compared to other staples. In Nigeria, it is the third most consumed crop in the country (FAOSTAT, 2012) after Sorghum and millet, followed by rice, yams and maize. Akinpelu *et al.* (2011) mentioned that the consumption of cassava for poor household in urban areas is double that of non-poor households while in rural areas, the consumption of cassava by poor households is triple that of non-poor households. In Nigeria, cassava is consumed in all regions of the country. Although cassava is rich in carbohydrates, it is very poor in protein and vitamins and as such, several projects are underway to improve the nutrition potential of cassava (via the introduction of Vitamins A) so as to make the crop more suitable for combating hunger and food security issues.

In Nigeria, cassava products can be grouped into five categories. These are fresh root, dried roots, pasty products, granulated products and cassava leaves. A wide array of products can also be processed from cassava. Firstly, the freshly peeled tubers can be either boiled or roasted for food. Boiled tubers can also be further pounded or added to soup and stews. To prevent rapid deterioration, non-food products such as starch and chips (animal feed) can also be produced from the tubers. Chips can also be further grounded into a flour for human consumption (for the baking of pastries, pasta production etc). Fermented cassava can also be used for alcohol production or further processed into biogas (Kenyon and Ochieng, 2006). Most advanced processing forms can transform cassava into biodegradable packaging, starch sweeteners, etc.

2.2 Over view of Global Cassava Production Trend

Nigeria was leading in production and area harvested. Nigeria is the world's largest producer of cassava with other top producers being Thailand, Indonesia, Brazil, the Democratic republic of Congo and Ghana as shown in Table 2.2 and figure 2.1. It has been estimated that in 2014, Nigeria's production of cassava and area harvested reached 54.8 million tonnes and 7.1million hectares (FAOSTAT, 2015). Followed by Thailand and Indonesia, their production stood at about 30 million and 23.3 million respectively while area harvested in the two countries are about 1.35 million ha and 1.00 million ha respectively (Table 2.2) . Other African countries Ghana and Democratic republic of Congo ranked as the fifth and sixth world cassava producers respectively as shown in Table 2.2. Nigeria has consistently been ranked as the world's largest producer of cassava since 2005, (FAOSTAT, 2012). According to FAO estimates, 276,721,584 tonnes of cassava were produced worldwide in 2013. Africa accounted for 57%, Asia for 32%, and others 11% of the total world production, (Tesfaye, *et al*., 2016). A total of 20,732,192 hectares was planted with cassava throughout the world in 2013; about 64% of this was in sub-Saharan Africa. The average yield in this year was 11.3 tons per hectare, but this varied from 1.3 tons per hectare in Burkina Faso to 35 tons per hectare in India. Being the largest producer, Nigeria, the average yield was 14 tons per hectare (FAOSTAT, 2013).



Source: FAOSTAT, (2015)

Figure 2.1 Global Trend of Cassava Area Harvested in hectares and Production in tonnes.

Table 2.2 Major cassava producing countries in the world (2014)

Country	Area Harvested (Ha)	Yield (Kg/Ha)	Production (Tonnes)
Angola	755,874	101060	7,638,880
Benin	296,641	137,092	4,066,711
Brazil	1,567,683	148,257	23,242,064
Cameroun	328,240	149726	4,014,610
Columbia	257,621	102263	2,654,521
Ghana	889,000	185872	16,524,000
India	228,280	356355	8,139,430
Indonesia	1,003,293	233595	23,363,840
Cambodia	359,530	245747	8,835,330
Madagascar	476,580	64791	3,087,810
Malawi	210,210	233614	4,910,810
Mozambique	870,300	58770	5,114,750
Nigeria	7,102,300	772,026	54,831,600
Rwanda	195,910	161374	3,161,470
sierra leone	390,740	104292	4,075,090
Thailand	1,348,996	222551	30,022,052
Uganda	852,000	33005	2,812,000
D.P.R. Congo	2,056,420	80766	16,608,900
China	287,680	162691	4,680,290

Source: FAOSTAT, (2015)

The trends of area, production and yields of cassava in West Africa for a period of twenty (20) years for area harvested, production and yield were given by their computed figures, shown in Figures 2.2 and 2.3 and 2.4. The trends of area harvested and production show corresponding movements within the period studied. The movements show marked fluctuations of increases and decreases with the peak of production and yield observed in 2008 while production declined in 2009. There was progressive upward movement of production trend from 2010 to 2014 as shown in Figure 2.4, but there was corresponding decrease in yield trend from 2010 to 2014

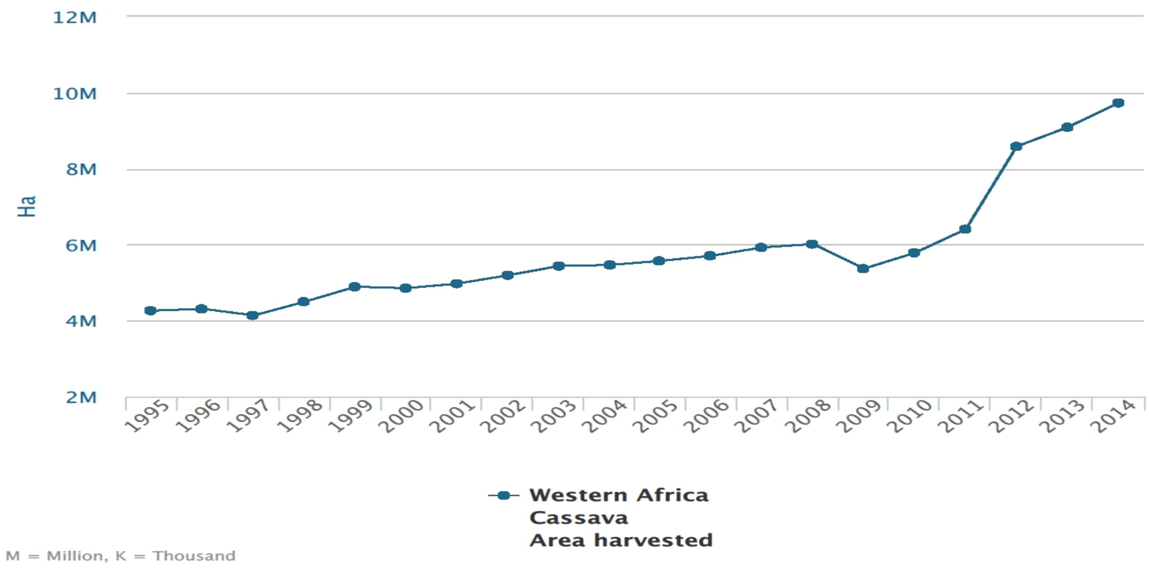


Figure 2.2 West Africa Trend of Cassava Area Harvested in hectares 1995-2014

Source: FAOSTAT, (2015)

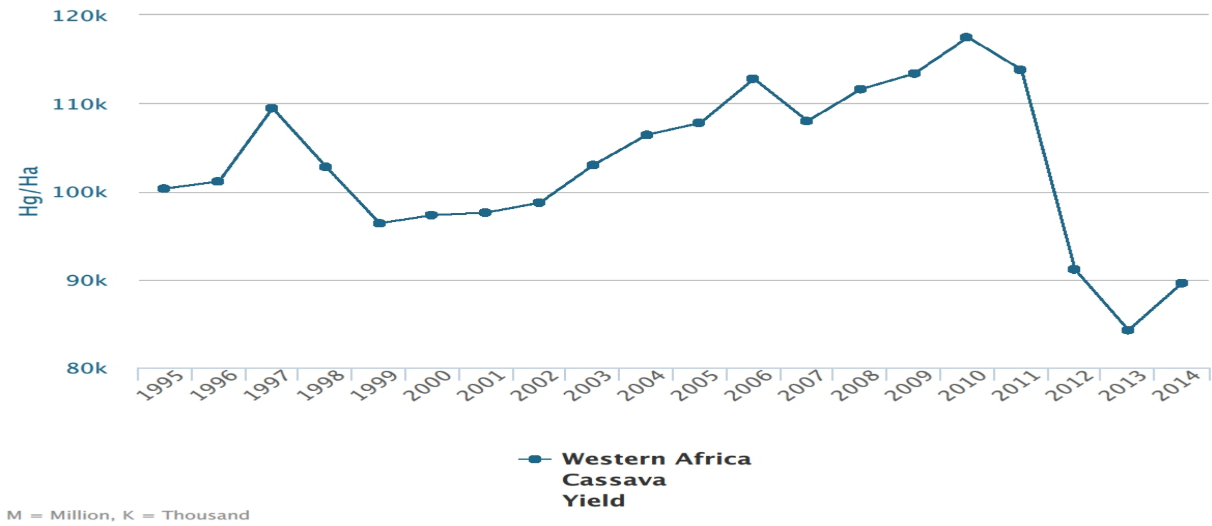


Figure 2.3 West Africa Trend of Cassava Yield in kg/Ha 1995-2014

Source: FAOSTAT, (2015)

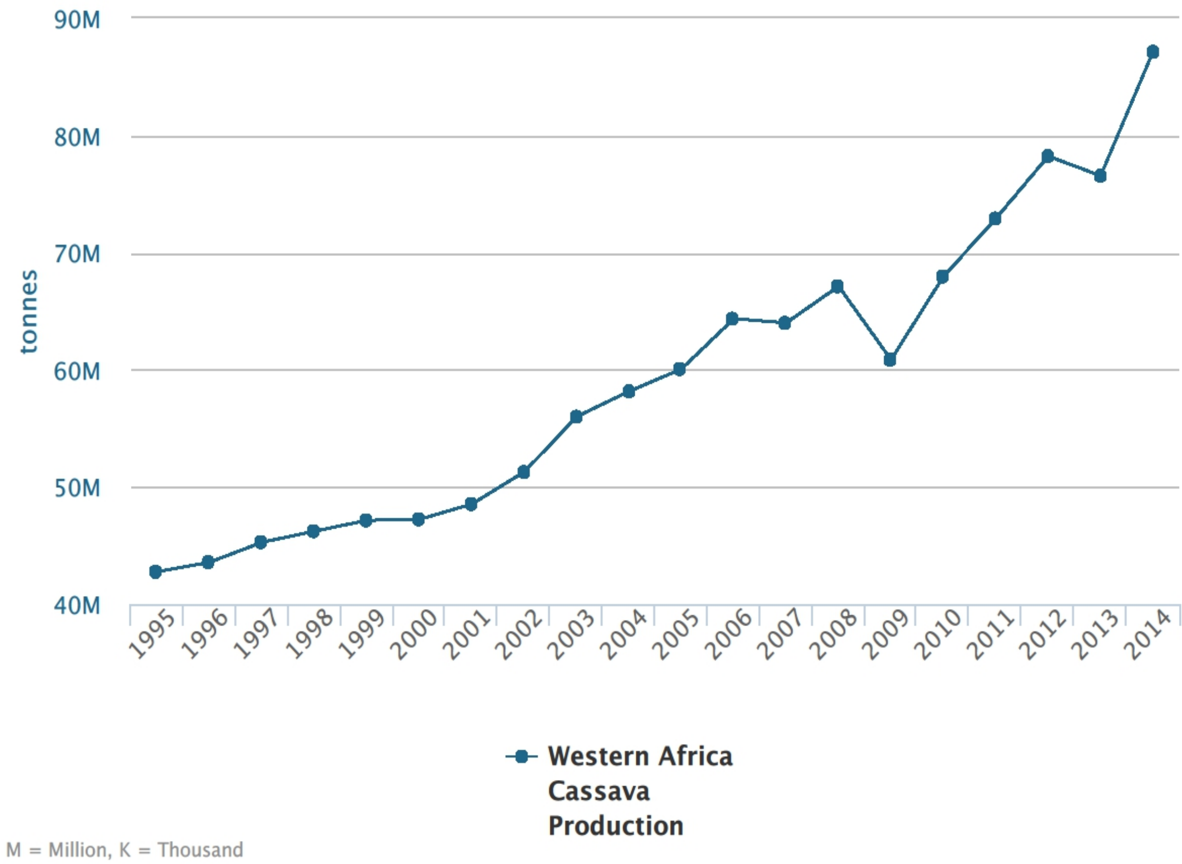


Figure 2.4 West Africa Trend Cassava Productions in Tonnes 1995-2014

Source: FAOSTAT, (2015)

2.3 Trends of Cassava Production, Area, and Yield in Nigeria

As reported by FAOSTAT (2015), the production trend of cassava in Nigeria has experienced increase in area planted and yield from 1995 to 2014. Table 2.3 shows that area harvested for cassava in Nigeria in 1995 were 2,994,000 hectares but in 2014 the area harvested increased to 7,102,300 hectares. Similarly, cassava production in tonnes increased from 31,404,000 tonnes in 1995 to 54,831,600 tonnes in 2014. This development within two decades has been attributed to the significant advances made on cassava variety improvement in Nigeria by International Institutes for Tropical Agriculture (IITA), National Root Crops Research Institutes (NRCRI), Umudike in collaboration with National Co-ordinated Research Programme (NCRP) on cassava (Eke-okro and Njoku 2012). UNIDO, (2006) and FAO, (2013), also reported that a number of varieties have been developed which combine diverse plant type, different maturity periods and resistance to several diseases, insect pest and parasitic weeds and they possess good agronomic traits.

The total land put to the production of the crop in 2014 was about 7.1 million hectares which represent an increase of 9.5% over that of 2013. The overall output of the crop in 2014 was estimated at about 54.8 million metric tonnes with an 8.6% increase compare to 2013. Benue State was the leading Cassava producing state in Nigeria as indicated in table 2.4, with an average mean production of about 3,771,320 metric tonnes, cultivated area of 340,548 hectares and yield of 110,743 kg/ha between 2005 and 2010 (NBS, 2011). Kogi state was the second largest cassava producer in the country with an estimated mean production of 2,897,656 tonnes, cultivated area of about 169,846 hectares and yield of 170, 605 kg/ha while Cross Rivers state was the third largest cassava producer in the country with an estimated mean production capacity of 2,671,424 tonnes, cultivated area of about 296,644 hectares and yield of about 90,055 kg/ha between 2005-2010. (NBS, 2011). Table 2.4 shows that Cross Rivers cultivated more area of land than Kogi state but Kogi state produced more Cassava than Cross Rivers state.

Table 2. 3 Nigeria's Trend of cassava production, area harvested, yield (1995-2014)

Year	**Area Harvested (Ha)**	**Production (tonnes)**	**Yield (Kg/Ha)**
1995	2,994,000	31,404,000	106,671
1996	2,946,000	31,418,000	106646
1997	2,697,400	32,050,000	118818
1998	3,042,500	32,695,000	10746
1999	3,406,000	32,697,000	95998
2000	3,300,000	32,010,000	97,000
2001	3,340,000	32,068,000	96,012
2002	3,446,000	34,120,000	99,013
2003	3,490,000	36,304,000	10,423
2004	3,531,000	38,845,000	110,011
2005	3,782,000	41,565,000	109,902
2006	3,810,000	45,721,000	120,003
2007	3,875,000	43,410,000	112,026
2008	3,778,000	44,582,000	118,004
2009	3,129,030	36,822,250	117,679
2010	3,481,900	42,533,180	122,155
2011	4,120,166	46,190,248	112,108
2012	6,401,996	50,950,292	79,585
2013	6,741,300	47,406,770	70,323
2014	7,102,300	54,831,600	77,203

Source: FAOSTAT, (2015)

Table 2.4 Major Cassava Producing States in Nigeria (2005-2010)

States	Area Harvested (Ha)*	Production (tonnes)*	Yield (kg/Ha)*
Benue	340,548	3,771,320	110,743
Kogi	169,846	2,897,656	170,605
Cross Rivers	296,644	2,671,424	90, 055
Enugu	218,270	2,632,958	120,628
Taraba	220,844	2,447,384	108,878
Kaduna	224,782	2,253,408	100,249
Ondo	105,308	2,051,398	194,800
Oyo	162,286	1,977,694	121,865
Imo	167,652	1,969,360	117,467
Akwa Ibom	130,230	1,843,490	141,556
Rivers	112,734	1,543,876	136,949
Anambra	109,272	1,521,880	139,247
Delta	100,004	1,452,974	145,292
Ogun	92,176	1,340,790	145,460
Ekiti	54,696	1,154,672	211,107
Nassarawa	82,320	1,094,002	132,897
Ebonyi	68,990	879,380	127,465
Kwara	68,520	819,840	119,650
Osun	50,390	609,466	120,950
Lagos	44,450	430,106	96,762

Source: NBS, 2011

Note: *Data are means from 2005-2010

2.4 Theoretical Framework

2.5 Grafted Polynomials

Grafted models are used in econometrics to embark on economic analysis involving time series. It was assumed that different functional forms may fit different segments of a time series or response studies. Segments of polynomials can be used to approximate production surfaces or frontiers and to forecast time series. The segment to be used to forecast time series as in trend studies must end in a linear form. These segmented curves are restricted to be continuous and differentiable at the joined points, (Odedukun, *et.al.,* 2013). There are relatively few studies that estimate agricultural projection/forecasting in developing countries such as Nigeria, (Olayiwola, 2014). Most of these have come out with rather surprising and paradoxical results of declining projection in the developing countries even in the years which are well documented for success stories where green revolution varieties of cassava has been widely adopted.

The studies of agricultural projection in developing countries include work done by Olayiwola, (2014), he analysed short term market forecast for cassava crops in Oyo state, Nigeria. The result of analysis indicated that the forecasted price per tons during October, November and December 2014 was 1161, 1151, 1177 naira's respectively. In November 2014 price decline to 1151 naira per tons. In October month actual model price prevail in the market was 1161 naira per tons. The forecasted price was less than the government support price of cassava during the agricultural year 2014-15 (1360 naira per quintal).

A study was also conducted by Odedukun, (2014), to forecast cotton production trend with the application of a grafted polynomial function in Nigeria from 1985 through 2013. A two-time segments function (quadratic-linear) was suggested by the researcher after grafting. The grafted (mean) function gave more reliable ex-post forecasts rather than merely fitting a linear function to the data used. Also Odedukun *et al.,* (2015), applied a grafted polynomial model "quadratic-quadratic-linear" function to predict cotton production trends based on time series data from 1995 to 2013 in Zamfara state, Nigeria. The values of the grafted (mean) function of 123,000 tons were closer to the observed values of 129,000 tons resulting in smaller difference during the sub- period (2006-2013) under consideration when compared with linear values of 137,000 tons. The forecast of production and supply trends among cotton farmers revealed that the grafted model provided better estimates since they were closer to the observed values during the sub-period under consideration.

Badmus and Ariyo (2011), used Auto Regressive Integrated Moving Average (ARIMA) model to analyse maize projection in Nigeria. Their findings showed that maize production for the year 2020 will be 13425.64 tons. Suleiman and Sarpong, (2012), employed the Box-Jenkins approach to model milled rice production in Ghana using time series data from 1960 to 2010. Although, a ten years forecast with the model shows an increasing trend in production, the forecast value at 2015 (283.16 thousand metric tons) was not good enough to compare with the 2012 rice production of Nigeria (2700 thousand metric tons), the leading producer of rice in West Africa.

Najeeb *et al.* (2005), employed Box-Jenkins model to forecast wheat area and production in Pakistan. Kirtti and Goyari (2013), used kink exponential growth rate model to analyse growth rates of area, production and yield of major crops in Odisha for pre-liberalization and post-liberalization periods. The results show that all crops, except rice experienced deceleration in area during post-liberalization period. Among those crops, bajra, jowar, wheat, ragi and small millet experienced a higher deceleration. Even the positive growth rate of rice area was very trivial.

Bivan, (2013), investigates the performance of linear and grafted polynomial functions in forecasting sorghum production in Nigeria. A three-time segments function was therefore suggested and estimated after grafting. The resulting mean (grafted) function provided more reliable ex-post forecasts of sorghum production than those yielded from merely fitting a linear function to the data used. The researcher concluded that sorghum production trend predicted with the grafted function is closer to the observed trend when compared to that of the linear function because it resulted in smaller differences. The researcher affirmed that the grafted function incorporated the major observed local trends in the forecasting framework.

Nmadu, *et al., (*2009), tested the possibility of the type of spline function and joint points selected affecting the consistency of the ex-post and ex-ante forecasts using cereal production (1961-2006) and percent contribution of agriculture to GDP (1961-2004) in Nigeria. The researchers used three types of model, that is, Linear-Quadratic-Linear, Quadratic-Quadratic-Linear and Linear-Quadratic-Quadratic. The researchers concluded that there is no universality as to which model is appropriate, rather all possible models should be tried and the one that gives most consistent result when compared to observed data and other factors should be used.

2.6 Supply response Model

Supply response measures the degree to which the level of production and/or marketed surplus changes in response to stimuli provided by changes in some important variables mainly prices, (Phiko, 2013). Supply response seek to explain the behaviour change of the producers with respect to production, consumption and exchange decisions for a certain product or set of products arising from changes in economic incentives (Ajetomobi, 2010). Rational price sensitivity on the part of the producers will presuppose desirable responses to changes in prices. Conversely, insensitive producer behaviour is construed as insignificant or lacking output responsiveness despite notable changes in prices. According to Ajetomobi, (2010), abolition of marketing boards and liberalisation of the agricultural markets are hypothesised to increase the nominal effective protection of the farmers even as the ratio of domestic price to border prices increases.

The supply response literature has gone through several important empirical and theoretical modifications, out of which two major frameworks have been developed. The first approach is the Nerlovian partial adjustment model, which allows analyzing both the speed and the level of adjustment from actual towards desired output (Nmadu, 2002, Nmadu, 2010). The second is the supply function approach, derived from the profit-maximizing framework. This latter approach requires detailed input prices and simultaneous estimation of input demand and output supply equations. However, input markets, in particular land and labour markets, are either missing or imperfect in several developing countries. Thus, the econometric approach in the present day studies are in line with the partial adjustment framework, enhanced with dynamic response, alternative price expectation assumptions and the introduction of price-risk variables (Hummel *et.al.,*2010; Van Rompay and Pryun, 2011).

2.6.1 Review of relevant studies on supply response

Numerous research studies have been undertaken worldwide in the area of supply response. Recent studies increasingly focused on developing countries in Africa and Asia such as, Nigeria, Zimbabwe, Botswana, Namibia, Zambia, Ethiopia, South Africa, India and Pakistan. Earlier studies on supply response primarily focused on one commodity, where price responsiveness was the major factor which influenced supply. More recent studies used dynamic and improved quantitative methods to measure supply response.

Adesiyan *et.al*., (2012), analysed Market supply response of Cassava in Ile-ife, Osun State, Nigeria, the researchers used multiple regression to determine the factors affecting the marketed surplus of the different crops and the extent of actual impact of each factor. The regression result shows that all the explanatory variables were statistically significant. The R^2 value was 97% indicating that about 97% of the factors causing variations in the marketed surplus of cassava were explained. The most important factor which increased marketed surplus significantly was the increased output followed by the quantity consumed at home and quantity given as gifts. The land size, losses and market distance similarly had negative and significant effects on marketed surplus. The elasticity of the marketed surplus with respect to output turns out to be positive and greater than unity (1.6). This shows that an increase in the price of cassava will lead to a corresponding increase in the marketed surplus and a reduction in the quantity consumed at home.

Onwumere and Ichie, (2014), studied the response of Nigerian cassava expansion initiatives to climate changes, economic growth and some policy instrument (1970-2012). The researchers adopted error correction model (ECM) using the Engle-Granger method. The result revealed a very high rate of adjustment to long run equilibrium and the variables are correlated which means that impact of each variable on cassava output behavior in the economy is inseparable. The Error correction coefficient of -0.975 measures the speed of adjustment towards long run equilibrium earned the expected negative sign and is statistically significant at 1% risk. The exchange rate elasticity in the short run is 1.867153 and significant at 5% level. This shows that 1% increase in the exchange rate will lead to a 187 expansion in the aggregate cassava output in the short run.

Ajetomobi, (2010), analysed supply response, risk and institutional change in Nigeria. The researcher used Autoregressive Distributed Lag and Error Correction Models. The results indicate that producers are more responsive not only to price but to price risk and exchange rate in the structural adjustment programme (SAP) period than in the commodity marketing board (CMB) period. The researcher contended that following deregulation, price risk needs to be meaningfully reduced for pulse and export crops, especially cowpea and cocoa.

Ogundari K., (2016), estimated the response of maize supply to prices in Nigeria using both Modified Ordinary Least Square (MOLS) and Ordinary Least Square (OLS) estimators, the empirical findings show that maize supply responds significantly and positively in the long run to own price and negatively (positively) to the price of cassava (yam), but maize supply failed to respond significantly to changes in all the prices in the short run. While the maize findings show that short run causality runs only from price of cassava to maize supply, the long run causality runs from joint effect of the prices to maize supply. The estimated speed of adjustment has negative sign as expected, but very low at 10% level of significance.

Akanni and Okeowo, (2012), examine the various determinants of the quantities of cereals (rice, maize, millet and sorghum) that are supplied into the Nigerian economy. Equilibrium output supply function and co-integration models were employed. An all -time maximum output of 8,090,000 tonnes was recorded for rice followed by millet with 7,100,000 tonnes with mean values of 4,228,900.47; 4477, 026.31; 3,596,894.73 and 2,034,719.00 for maize, rice, millet and sorghum respectively. Rainfall was consistent for all the four crops with an all- time maximum of 136.41 mm rainfall and mean value of 37.93 mm. Trace test reveals that the hypothesis of no co-integration (Ho: $r = 0$) is rejected at $p < 0.05$; given that the calculated Trace test statistic (98.45) is higher than the critical value (95.75) at $p < 0.05$. However, the test that $r \leq 1$ could not be rejected. Thus, Trace test reveals that the series in maize output supply response model are co-integrated, with only 1 co-integrating equation existing between them. Producer price of rice was positive and statistically significant at 1% level. The output response of rice to hectarage was not statistically significant but was positive. Rice importation showed a negative sign and was statistically insignificant in Nigeria. The research concluded that there was tendency for the price of agricultural products to drop, which may consequently reduce the level of domestic production and thus discourage commercial production.

Mesike *et., al* (2010), applied the vector Error Correction Model to measure the Supply Response of Rubber Farmers in Nigeria. Preliminary analysis suggested that estimations based on their levels might be spurious as the results indicated that all the variables in the model were not stationary at their levels. Further results indicated that producers' prices and the structural break significantly affected the supply of rubber. Response of rubber farmers to price were low with an estimated elasticity of 0.373 in the short-run and 0.204 in the long-run due to price sustainability and the emergence of other supply determinants indicating significant production adjustments based on expected prices. Policy efforts in promoting sustainable marketing outlets and promoting high value and high quality products for export were suggested in understanding farmer's responses to incentive changes.

Phiko, (2013), assessed the hectarage response of smallholder farmers in maize production to price and non-price incentives Malawi. The study employed an Auto-regressive Distributed Lag model (ARDL). Time series data for a period of 20 years ranging from 1989 to 2009 was used for the analysis. Study findings shows that the important factors affecting smallholder farmers' decision to allocate land to maize included the lagged hectarage allocated to maize, availability of labour and inorganic fertilizer. Lagged maize prices and weather were found to be statistically insignificant in influencing farmers' decision to allocate land to maize. The researcher concluded that the price incentives on their own are inadequate to influence smallholder farmers' decision to allocate land to maize. The reason given by the researcher was that farmers are largely constrained by land and cash resources with which to hire labour and to purchase inorganic fertilizer in order to respond to higher market prices. The researcher suggested that policy needs to go beyond market and price interventions as a means of incentivizing staple food production as non-price incentives are critical in influencing smallholder farmers' production decisions in relation to maize in Malawi.

Oyewumi *et al.,* (2011), studied the supply response of beef in South Africa using the error correction model. The results of the study confirmed that beef producers in South Africa respond to economic, climatic, trade and demographic factors in the long-run. In the short-run, however, the study showed that cattle marketed for slaughtering were responsive to climatic factors (i.e. rainfall) and imports of beef. Animal demographics, producer price of yellow maize and the producer price of beef were found not to have a short-run effect on cattle marketed for slaughtering.

Olawande *et al.,* (2009), studied the supply responsiveness of maize farmers in Kenya. The results of the study showed that maize price support is an inadequate policy for expanding maize supply. Fertilizer use was found to be particularly important in the decisions on resource allocation in maize production. Of the fixed inputs, land area was found to be the most important factor contributing to the supply of maize. It is suggested that making fertilizer prices affordable to small holder farmers by making public investment in rural infrastructure and efficient port facilities, and promoting standards of commerce that provide the incentives for commercial agents to invest in.

Similar recent empirical applications in Asia include supply response estimations by Yu and Fan (2011) for rice production in Cambodia, Mostofa *et al.,* (2010), for vegetable production in Bangladesh, and Ime *et al*., (2011), for several agricultural commodities for a panel data of ten Asian countries. There are also several econometric studies on the advanced economies. For the US, for instance, Huang and Khanna, (2010), model the supply response of specific agricultural commodities to own and cross-prices whereas Roberts and Schlenker, (2010), estimate the aggregate supply response of calories to world food prices. Supply response models by Sanderson *et al.,* (2012), for wheat and by Agboola and Evans, (2012) for rice and cotton acreages are two examples of such studies on Australia. Slightly modified versions of such a partial adjustment framework were also applied for econometric estimation of crop production and acreage in some provinces of Canada. These include studies by Coyle *et al.,* (2008) for the estimation of acreage and yield response models for wheat, barley and canola in Manitoba and by Weersink *et al*., (2010), for the estimation of acreage responses of corn, soybeans and winter wheat in Ontario.

2.6.3 The Nerlovian Model Framework

There have been a wide variety of applications of the Nerlovian model with certain modifications of the original framework. Alternative expectation assumptions such as futures prices as additional information used for price expectation formation (Gardner, 1976), expected net returns rather than prices alone, and output/land value rather than prices or returns have been used (Bridges and Tenkorang, 2009). Risk variables have also been included to capture the behavioral aspects of farmers (Lin and Dismukes, 2007). Furthermore, econometric developments have allowed more recent work to use panel data while time series data have often been used to capture the dynamics of agriculture production in earlier studies.

Nmadu, (2010), in his review of the Nerlovian partial adjustment framework and its application to sorghum production in Nigeria, shows how varying coefficients of adjustment might be incorporated into the Nerlovian partial adjustment framework and the resulting model applied to sorghum production in Nigeria. The nonlinear forms of the model were estimated with quasi Newton iteration technique while the linear forms were estimated with regress. The estimated coefficients conform to theoretical expectations and were appropriately signed but with few exceptions. In addition, varying elasticity of supply was also obtained. The distribution of the adjustment coefficient and the elasticity were significantly different from zero.

Ime, (2014), applied Nerlovian adjustment model to estimate aggregate agricultural output supply response in Akwa Ibom State of Nigeria. The estimated coefficients were very low, indicating weak or minimal contributions of the variables to output growth in Akwa Ibom State. Moreover, the estimated short-run and long-run elasticities were fairly inelastic.

However, the adjustment coefficient which measures the speed and magnitude of changes in planned output in response to anticipated output was above average. Based on his findings, he concluded that farmers in Akwa Ibom State were more responsive to policy incentives. He suggested that more of these factors should be committed to agricultural production, so as to improve productivity.

Nkang, *et al.,* (2006), employ Nerlove adjustment model in the estimation of staple food policy and supply response in Nigeria: A case of cassava. The empirical results show that short-run changes in own-price, cross-price, lagged hectarage and capital expenditure on agriculture all play a significant role in shaping cassava supply behaviour between 1970 and 2002 in Nigeria. Moreover, the long run sensitivity of hectarage to own-price is elastic, given an adjustment coefficient of 0.6718 (implying that the rate of farmers' adjustment to long-run equilibrium is about 67%). According to researchers, these estimates carry some policy implications. The own-price elasticity cassava hectarage in the short- and long-run was 0.7108 and 1.058 respectively, meaning that own-price is inelastic in the short-run and almost unitary elastic in the long-run. Thus, a 10% rise in the price of cassava, ceteris paribus, would lead to a 7.10% and 10.58% expansion of cultivated cassava hectarage in the short- and long-run in that order. This implies that hectarage supply of cassava is highly sensitive to price signals in the long run. The researchers maintained that improved cassava pricing would evoke a larger than proportionate supply response by cassava farmers. The cross-price elasticity was also 0.8904 indicating that cassava and rice are substitutes in production. Thus, a 10% decrease in the price of rice would lead to an 8.9% expansion in cassava hectarage in the short term. Although the elasticity of the fiscal policy variable (capital expenditure on agriculture), 0.4029, was inelastic in the short-run, its statistical significance has some implications. They concluded that the aggregate nature of this variable, its changes are likely to dampen the effect of changes in variables like input availability/cost in explaining smallholder supply

Conteh, *et al.,* (2014), applied Nerlovian adjustment model to assess the response of farmers to price and other related factors in rice production in sierra Leone. They utilized ordinary least square (OLS) technique to determine the coefficients of acreage response models for the rice varieties. The magnitudes of the coefficients (λ) of both the ROK lagged and NERICA lagged acreages were found positive and highly significant, which indicates that farmers' adjustment rate was very low. Regarding lagged actual price for both the ROK and NERICA rice varieties, the short-run price elasticities were lower than long-run, which is suggesting a long term adjustment of the acreage under the crop. However, their recommendation for policy transformation is to open farm gate prices and to decrease government's involvement in agricultural sector especially in the acquisition of agricultural inputs.

Using panel data for the period 1970/1971 to 2004/2005 across the states of India, Mythili, (2008), estimates short and long-run supply elasticities for a set of crops in the country. Panel econometric estimation based on a pooled cross-sectional data over this period shows that Indian farmers respond to price incentives in the form of both acreage expansion and yield improvement. The study also indicates that acreage adjustment to desired levels is slow in India.

Another study by Kanwar and Sadoulet, (2008), also applied a variant of the Nerlovian model to estimate output response of cash crops in India using panel data for the period 1967/1968 to 1999/2000 across 14 states in the country. They also apply dynamic panel estimation techniques using expected profit instead of expected prices and find that expected profit has statistically significant positive impact on five out of seven cash crop acreages.

A recent study by Yu *et al*., (2012), has applied similar framework to estimate the acreage and yield response of different winter and summer season crops for the province of Henan in

China. Using data from 108 counties in the province for the period 1998-2007, the study found variable responses to output prices of acreage and yield across crops.

Studies show responsive agricultural output to crop prices, albeit with lower magnitude as compared to responses in most advanced economies. For instance, Vitale *et al.,* (2009), used farmer level data for the period 1994-2007 in Southern Mali in order to estimate a supply response model for major staple crops in the region. This study reported statistically significant acreage responses with respect to own-crop prices and, in most cases, to cross-prices as well. Muchapondwa, (2009), estimated aggregate agricultural supply response models for Zimbabwe for the period 1970-1999. The study found short-run price elasticity of supply consistent with theory; however, the long-run elasticity is only significant at 10% and is atypically smaller than the short-run value. Other supply response studies include Subervie, (2008) on aggregate agricultural commodity for many African and other developing countries, Leaver, (2004) on tobacco supply in Zimbabwe, and Molua, (2010) and Mkpado *et al.*, (2012) for rice supply in Cameroon and Nigeria, respectively.

Other applications of supply response work have also been conducted for Latin American countries. A national soybean supply response model by de Menezes and Piketty, (2012) using state-level data in Brazil for the period 1990-2004 found that soybean supply is price elastic. Another Brazilian acreage response study by Hausman, (2012) also found stronger response to crop prices for soybean acreage but weak response in case of sugar cane. Furthermore, Richards *et al*. (2012), estimated soybean supply response equations for three Latin American countries using data from the middle of the 1990s. Their econometric results show significant soybean acreage response to own output prices in all these countries with stronger response in Brazil, followed by Bolivia and Paraguay.

2.6.3.1 Empirical Nerlovian Model

The model was developed by Nerlove. Hence, following Nerlove (1979) tradition, the general supply response can be presented as:

$Q_t^e = b_0 + b_1P_t^e + b_2W_1 + U.$ (1)

Where Q_t^e is desired level of output, P_t^e is a vector of expected level of prices, Wt represents the set on non-price factors, bi‟s are parameters and Ut accounts for unobserved random factors with zero expected value, (Zhao, 2010 and Schreinemachers and Berger, 2011). What this model is saying is that the desired level of output depends on the expected price level and other non-price factors. This model assumes a linear relationship. The Nerlovian model is constructed to handle two dynamic processes: adaptive expectations and partial adjustments (Lambert, *et. tal*, 2012 and Harris and Nguyen, 2013). Since the desired level of output cannot be obtained by farmers due to policy constraint, Nerlove postulate the following hypothesis, known as partial adjustment.

$Q_t – Q_{t-1} = \gamma\ (Q_t^e – Q_{t-1}),\ 0< \gamma < 1$ (2a)

γ is known as the coefficient of adjustment, Q_t - Q_{t-1} is the actual change in output and (Q_t^e - Q_{t-1}) is the desired change in output.

Equation (2) is saying that the actual change in output in any given time period t is some fraction γ of the desired change for the period. If $\gamma = 1$, it means that the actual output is equal to the desired output, that is, actual output adjusts to the desired output instantaneously in the same time period. However, if $\gamma = 0$, it means that there is no change since actual output at time t is the same as that observed in the previous time period. Typically, γ is expected to lie between these extremes since adjustment to the desired output is likely to be constrained by policy lags.

Specification of a model that explains how price expectations are formed based on differences between actual and past prices assumes:

$$P_t^e - P_{t-1} = \lambda (P_{t-1} - P_{t-1}), O < \lambda < 1 \quad (2b)$$

Where, λ is the adaptive expectations coefficient. Specifically, equation three states that expectations are revised each period by a fraction λ of the gap between the current value of prices and its previous expected value. This means that expectations about the price level are revised by farmers by a fraction λ due to policy inconsistency that affect the price level observed in the current period and what its anticipated value had been in the previous period. If $\lambda = 1$, it means that expectations are realized immediately and fully, that is, in the same time period. If, on the other hand, $\lambda = 0$, it means that expectations are static, that is, conditions prevailing today will be maintained in all subsequent periods. However, expectations are seldom fully realized, there is usually a gap between actual and expected level of prices because of constraint in public policies and non-policy variables.

In order to use the Nerlovian model for estimation, it is necessary to transform the three equations into the reduced form. In the reduced form, the partial adjustment variable Q_t^e which is associated with the desired output and the adaptive expectation variable P_t^e which is associated with price expectation are transformed into distributed lag structures in the form of past level of output and the previous expected price level, (Lusardi and Mitchell, 2011 and Hendricks, 2013). This is consistent with the Nerlovian model which is based on price expectation and output adjustment. The entire process necessary to arrive at the reduced form equation is shown below. There are two constants in the equation, γ and λ. γ is referred to as the Nerlovian coefficient of adjustment. By imposing a restriction that $\lambda = 1$ and substituting equations (3b) and (3c) into equation (3a), a reduced form equation is derived as follows:

$$Q_t^e = b_0 + b_1 P_t^e + b_2 W_1 + U. \quad (3a)$$

$$Q_t - Q_{t-1} = \gamma (Q_t^e - Q_{t-1}), 0 < \gamma < 1 \quad (3b).$$

$$P_t^e - P_{t-1} = \lambda (P_{t-1} - P_{t-1}),\ O < \lambda < 1 \tag{3c}$$

$$Q_t^e = b_0 + b_1P_{t-1} + b_2W1 + U_1 \tag{4}$$

Substitute equation (4) into equation (3b):

$$Q_t = Q_{t-1} + \gamma(b_0 + b_1P_{t-1} + b_2W1 + U_1) - \gamma\ Q_{t-1} \tag{5}$$

Remove bracket

$$Q_t = Q_{t-1} + \gamma b_0 + \gamma\ b_1P_{t-1} + \gamma b_2W_1 + \gamma U_1) - \gamma\ Q_{t-1} \tag{6}$$

Collect like terms

$$Q_t = \gamma b_0 + \gamma\ b_1P_{t-1} + \gamma b_2W_1 + (1-\gamma)\ Q_{t-1} + \gamma U_1$$

The equation becomes:

$$Q_t = a_0 + a_1P_{t-1} + a_2W_1 + a_3Q_{t-1} + U_1 \tag{7}$$

Where:

$a_0 = \gamma b_0$

$a_1 = \gamma\ b_1$

$a_2 = \gamma b_2$

$a_3 = 1-\gamma$

$U_1 = \gamma U_1$

Hence,

$a_3 = 1-\gamma$

Therefore, $\gamma = 1 - a_3$

$a_0 = \gamma b_0$

$a_0 = (1 - a_3)\, b_0$

Therefore, $b_0 = \frac{a0}{1-a3}$

$a_1 = \gamma\, b_1$

$a_1 = (1 - a_3\,)\, b_1$

Therefore, $b_1 = \frac{a1}{1-a3}$

$a_2 = \gamma b_2$

$a_2 = (1 - a_3)\, b_2$

Therefore, $b_2 = \frac{a2}{1-a3}$

The above equation was adopted by Conteh, *et.al.,* 2014 and Ime, 2014. The 'a' parameters are the short-run elasticities while b is the long-run elasticities. 1-a_3 is the coefficient of adjustment. Equation (7) is the reduced form of the Nerlovian model. It says that the current level of agricultural output Q_t is determine by the autonomous output a_0, the previous expected level of prices, P_{t-1}, a set of non-price variables W_t, the past level of output Q_{t-1} and on the disturbance term Ut. While equation (7) depicts the theoretical description of the Nerlovian model, its final form for empirical estimation must capture the relevant factors underlying agricultural supply. Agricultural supply represents the response of farmers to changes in farm profits. Changes in farm profits, however, are the result of the interplay of changes in prices and non-price factors. Available empirical findings tend to suggest that the association between real farm prices and agricultural output is weak, which implies the importance of non-price factors in determining farm output, (Pao and Tsai, 2011; Potgieter *et. al.*, 2010).

2.6.3.2 Relevance of the Model

Among all the econometric models used in measuring the responsiveness of agricultural supply to policy measures, the Nerlovian model is considered one of the most influential and successful, judged by the large number of studies which utilized this approach, (Ime, 2014). Some of the researchers that utilized the model are:(Lin and Dismukes, 2007; Brigdes and Tenkorang, 2009; Ajetombi, 2010; Hummel *et. Al.,*2010; Van Rompay and Pryun, 2011; Mekbib and Mathias, 2013; Ime 2014; Conteh, *et., al.*, 2014 and Bingxin, Fengwei and Liangzhi, 2015).

Researcher prefers using the model because it recognizes the effect of time lag on the current level of output. It takes sometime before farmers can embrace new policies such as the adoption of new farming methods like crop spacing, planting of new improved seeds and application of modern inputs like fertilizers and chemicals etc, which improve crop yield. Nerlove has built in this time lag into the model as part of the explanatory variables where output lagged by one period, (Q_{t-1}) and real price lagged by one period (P_{t-1}) are meant to capture the length of time needed by farmers to adopt new policies. Other models such as the profit function, production function, error correction and co-integration model, linear programming and ordinary least square methods often used by researchers do not recognize the influence of time lag on agricultural production. In addition, the model is very flexible. It can handle the growth process in the agricultural output and the estimation of long-run and short-run elasticities. Furthermore, in the Nerlovian model, the stochastic disturbance term U is uncorrelated with the lagged explanatory variable Q. In this model U = γU, where O <γ< 1. Therefore, if U satisfies the assumptions of the classical linear regression model so will γU.

Thus, ordinary least square (OLS) estimation of the Nerlovian model will yield consistent estimates in the coefficient of the variables. The reason for consistency is this. Although Q_{t-1} depends on U_{t-1} and all the previous disturbance terms, it is not related to the current error term U. Therefore, as long as U is serially independent, Q_{t-1} will also be independent or at least uncorrelated with U, thereby satisfying an important assumption of OLS, namely, non-correlation between the explanatory variable and the stochastic disturbance term. In addition, in order to ensure the normality of the residuals, it is possible to express the Nerlovian model in logarithmic form. The transformation ensures that the errors are both homoscedasty and normally distributed. The logarithmic form also allows the interpretation of coefficient as elasticities.

2.6.3.3 Limitations of Nerlove Model

The Nerlovian approach used OLS to estimate the dynamic specification of the supply response. This means that the estimates of aggregate agricultural supply response are based on the assumption that the underlying data process is stationary. Most economic variables including agricultural time series tend to be non-stationary, however; i.e., their first two moments, means and variance are not constant. Using OLS with non-stationary variables may result in spurious regressions (Tripathi, 2008, Muchapondwa, 2009 and Ajetomobi. 2010). To ensure stationary variables, the equation could be reformulated in terms of differences, but this loses important information conveyed by the levels, such as information on long-run elasticities. The dynamics of supply in the Nerlove model is driven by the partial adjustment hypothesis that farmers move closer to their equilibrium position by some fraction each Supply Response. When variables are co- integrated (I, 1) there is a general and systematic tendency in the series to return to their equilibrium value; short-run discrepancies may be constantly occurring but they cannot grow indefinitely. This implies that the dynamics of adjustment are intrinsically embodied in the theory of co- integration, and in a more general way than encapsulated in the Nerlove partial adjustment hypothesis. The Granger representation theorem states that if a set of variables is co- integrated (1,1), implying that the residual of the co- integrating expression is of order I(0), then there exists an ECM describing that relationship. An alternative approach to Nerlove method is the used of co-integration analysis.

2.6.4 Response variables (area and yield)

In general terms, it is the planned total output that responds to price and non-price changes in supply response models. However, due to the non-availability of time series data on planned output it becomes necessary to use some appropriate proxy regarding the response variable through which the farmers' decisions are reflected. There is a great deal of disagreement in the literature on what the precise measure of output is. The three choices for measuring output are the acreage under cultivation, production or yield per unit area, and total production in terms of weight or tonnage produced. Some researchers claim that area under the crop could be a better proxy for the planned output. They argue that area statistics are not only readily available and more dependable but also least influenced by external factors.

Researchers indicated that, the choice of the proxy employed influences the results of the study. Most time series study for particular crops use acreage as the proxy for output. Mythili (2008) hypothesized that acreage response underestimates supply response and farmers respond to price incentives partly through intensive application of other inputs given the same area, which is reflected in yield.

Most directly, output is measured in terms of crop weight or volume produced or marketed, but in fact, the basic relationship between expected prices and cultivator reactions seems better expressed in terms, not so much of harvested tonnage, but rather of planted acreage is generally the best available method of gauging how cultivators translate their price expectations into action. Askari and Cummings (1977). From the various studies undertaken on agricultural supply response, some of the researchers who favoured area response are; (Nerlove (1958), Muchapondwa (2009), Mekbib and Mathias, 2013; Ime 2014; Conteh, *et., al.*, 2014 and Bingxin, Fengwei and Liangzhi, 2015).

On the other hand, Hertel and Keeney (2008) argued that the arrival of land saving technologies in modern agriculture makes land to become a secondary factor in production. Therefore, they implored for the yield/output response rather than the area response.

Another group of researchers, Mythili, (2008), worked on both area and yield responses in order to assess the farmers' response to price and non-price factors. Singh (1998) estimated the acreage response of the crop rather than its yield response while studying supply response of oilseeds in Uttar Pradesh. To justify this, the author indicated that the area enjoyed by the crops can be considered as a barometer of the farmers' land allocation decision. Further, the area allocation under a crop is a function of several endogenous factors, whereas, the yield is influenced by several exogenous factors. But, Singh also believed that the farmers could influenced by several exogenous factors. But, Singh also believed that the farmers could keep area constant and increase output by varying yield level.

Leaver (2003) estimated the supply response functions of tobacco in Zimbabwe. The author postulated that the best measure of output appears to be the use of the actual produce weight because it acknowledges that farmers may respond to price incentives by using either more intensive or more extensive farming techniques. An additional factor in favour of the use of this particular measure is that data on tonnage produced is readily available.

2.6.5 Price factor

The price factor remains a debatable issue among various supply response researchers. The main question as to which price (the pre-sowing prices, the post-harvest prices, the annual average prices, the absolute prices or the relative prices), influences the farmer's decision-making process remains unanswered. Farm prices are an important determinant of farm incomes which in turn affect the farmers' ability to increase the quantity and improve the quality of resources available to him.

The price variable used is usually a measure of relative prices; prices paid relative to prices received; output prices relative to input prices or crop price relatives. These are alternative measures of incentives and the choice among them is often dictated by the availability of reliable price data. Measures ofprice risk which are properly considered an element in price incentives are frequently not included.

Agricultural pricing policy plays a key role in increasing both farm production and incomes and is fundamental to an understanding of this price mechanism in supply response. Agricultural supply depends on prices of both output and input. The ultimate result from free market theory is that output price is the most important determinant of supply (Muchapondwa, 2009). If the output prices increase the profit increase and that motivates producers to produce more. Similarly, an increase in input prices leads to increase in production costs that depress supply. One of the initial decisions meeting the researcher is how to measure output price. In the original model, Nerlove expressed actual prices in terms of those currently obtainable in the market, whilst expected prices are described in terms of past market prices (Askari and Cummings, 1977).

2.6.6 Supply shifters

The total variation in the output is considered as a consequence of changes not only in the price factor but also in several non-price factors that have their bearing on production activity.

It could be said that the price variation at best, explains only a part of the variation in the response variable. The bulk of studies on supply response highlighting the importance of non-price factors such as weather variations, technology, policies and market access for both inputs and output, have also drawn adequate attention as they have a significant effect on the supply of maize. Non-price factors seem to dominate price factors in farmers' decision-making (Mythili, 2008; Askari and Cummings, 1977). A major source of differences among studies has to do with accurately adjusting for non-price factors affecting production such as weather, infrastructure and technological changes which may be associated with prices. This is serious for studies of yield response to prices. Studies differ in this regard depending on the availability of data on the author's judgment as to the relevance of a particular non- price factor.

A measure of weather variation seems to be most commonly encountered in most studies, with a wide variety of methods used to capture this concept; indices of rainfall, humidity and frost etc. Concepts essentially related to infrastructure seem important and measurable to most researches, and thus are directly included in the statistical analysis model. In other instances, yardsticks that are difficult to quantify are presented by proxy variables.

According to Askari and Cummings (1977), the time or trend variable is mainly used as a proxy to detect time-related effects on overall output such as advances in agro-technology and secular growth in the demand of the industrial and/or consumption sectors for the output of the agricultural sector. The decision to use a trend variable rather than a more direct measure of postulated influence on supply is generally based on difficulties in obtaining reliable time series data for the factor in question.

2.6.7.4 Stationarity/ Unit Root Test

The first step in carrying out a time series analysis is to check for stationarity of the variables. A series is said to be stationary if the means and variances remain constant over time. It is referred to as 1(0), denoting integrated of order zero. Non stationary stochastic series have varying mean or time varying variance. The purpose was to overcome the problems of spurious regression. A stationary series tends to constantly return to its mean value and fluctuations around this mean value have broad amplitudes, hence, the effects of shocks are only transient. Other attributes of stationary and non-stationary data and their implications in econometric modeling are discussed by Gujarati (1995) and Juselius (2006).

Unit root is a feature of processes evolves through time that can cause problem in statistical inference involving time series models. A linear stochastic process has a unit root if 1 is a root of the process's characteristics equation, such process is non-stationary. A unit root test, test whether a time series variables is non-stationary and possesses a unit root and the alternative hypothesis is generally defined as a unit root and the alternative hypothesis is either stationary; trend stationarity or explosive root depending on the test use-statistics. According to Abu *et.al.,* (2015), the Augmented Dickey Fuller (ADF) can be employed to test (unit root test) for the presence of the unit root (evidence of non-stationary). The advantage of the method lies on its robustness to handle both first order and higher order autoregressive processes. The model for stationary test can be presented as follows:

$$\Delta Y_t = a + Y_{t-1} + \Psi T + \sum_{k=0}^{N} \beta k \, \Delta Y_{t-1} + U_t \qquad (8)$$

Where:

Δ = first difference operator

Y_t = crops yield series being investigated for stationarity

T = time or trend variable

a, Ψ, β = parameters to be determined

U_t = error term

$$\Delta P_t = a + P_{t-1} + \Psi T + \sum_{k=0}^{N} \beta k \, \Delta P_{t-1} + U_t. \quad (9)$$

Where:

Δ = first difference operator

P_t = crops price series being investigated for stationarity

T = time or trend variable

a, Ψ, β = parameters to be determined

U_t = error term

Y_t or P_t has unit root if the regression δ = 0, otherwise the unit root does not exist (Iganiga and Unemhilin, 2011; Akintunde, *et. al.,* 2013 and Abu *et.al.,* 2015).

In order to ensure that the error term (ut) in the test model is empirically white noise, the optimum lag order (N) will be chosen where Akaike information criteria (AIC) is minimum within the lag range dictated by $l12$ rule(K_{max}.= $(12 \frac{T}{100})^{0.25}$

Where T = sample size

K_{max} = maximum lag order permissible for unit root test

Furthermore, the significance of coefficient δ will be tested against null hypothesis of unit root based on the computed ADF and tabulated Mackinnon critical values.

Decision rule: if the computed ADF statistic is greater than the critical value at specified level of significance, then the null hypothesis of unit root is accepted otherwise it is rejected.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Study Area

The study area is Nigeria. Nigeria with a total geographical area of 923, 768 square kilometers is located between latitudes 4°N and 14°N and longitudes 2°2' and 14°30' East. Nigeria has a total land area of about 91.07 million hectares, 77% of which is cultivable (agricultural) and 13% under forest and woodland, (Eboh, *et.al.*, 2004). Climatically, Nigeria is equatorial in the south, tropical in the centre and arid in the north. Mean maximum temperature ranges from 30^{O} to 32^{OC} in the south and 33 to 35°c in the north (Library of Congress, 2006). Nigeria's terrain has rugged hills, undulating slopes, gullies, waterlogged areas, and flat undulating land surfaces. Specifically, it is characterized by southern lowlands merging into central hills plateaus, mountains in the southeast and plains in the north.

Nigeria has highly diversified agro ecological conditions which makes it possible for the production of a wide range of agricultural products. In terms of employment, at least 60% of Nigeria's projected population of 160 million is estimated to be engaged or employed in agriculture (mainly small holders). Women make up to 60-80% of work or labour and produce two thirds of food crops, (Abu *et.al.*, 2015).

3.2 Method of data collection

Secondary data covering the period of 1961-2014 were used in this study. Secondary data used include prices, output and hectarage cultivated for Cassava, Yam and Sweet potatoes. Other data include rainfall, rain days, date of onset and cessation of rain, temperature and relative humidity. The data was collected from Food and Agricultural Organisation (FAO), Central Bank of Nigeria (CBN), National Bureau of Statistics (NBS), Federal Ministry of Agriculture, the World Bank, and Meteorological Stations.

3.4 Method of Data Analysis

Three models were employed in this study to achieve stated objectives. The models are growth model was used to achieve objective I, grafted response model (objectives ii and iii), Nerlove model using adaptive expectation model to achieve objective iv, Nerlove model using partial adjustment model to achieve objective v, Nerlove model using adaptive expectation and partial adjustment model to achieve objectives vi and vii.

3.5 Growth Rate and Doubling Time Functions.

This section assessed the growth rate of cassava production and doubling time of cassava production between 1961 and 2014 in relation to Structural Adjustment Programme (S.A.P.) and Agricultural Transformation Agenda (A.T.A.) policies during the period under study. Exponential function as well as the quadratic function in trend variables was used.

The exponential function is given as:

$$Y_o = ae^{bt} \tag{10}$$

Implicit of the model was linearized to give the following equation

$$\ln Y_o = a + bt + u \tag{11}$$

where: Y_o = crop variable: production (tonnes), hectarage (ha) and yield (kg/ha), t = trend variable 1961-2014, u = error term, b = estimated coefficient, a = constant. To determine the effect of macroeconomic policies on the cassava by measuring the acceleration and deceleration in cassava crop economy during the period under study, the log quadratic trend equation was estimated as follows:

$\ln Y_o = a + bt + ct^2 + u$ (12)

According to Ghosh, (2010), Ammani, (2015) and Nmadu *et tal.,* (2015), the positive significant value of 'c' indicates acceleration while a negative implies a deceleration and insignificant values implies stagnation in the growth process. The doubling time is the number of years it will take to double the rate of growth of a time series. The doubling function is presented as follows.

$$n = {ln2}/{ln\left[1+\left(\frac{r}{100}\right)\right]} \qquad (13)$$

Where n = doubling time (in years)

r = growth rate in (percent per year) obtained from the growth equation.

According to Barlett, (2011), the approximate life span of an American 69.7, the researcher indicated that when r = 1% per year, n = 69.7.

The formula therefore can be approximated by equation (14a)

DT = 69/r (14a)

(Barlett, 2011 and Nmadu, 2015) where DT = doubling time. In this study the doubling time was determined using 55 as the approximate life span of a Nigerian. United Nation Population Fund, (UNFPA, 2019). Thus equation (14a) is transformed into:

DT = 55/r (14b)

The compound growth rate was computed for each variable as follows:

$R = (e^{b-1}) \times 100$ (15)

Wher r = compound rate of growth, b = estimated coefficient from equation (10). Equation (10) and (12) were applied to the entire period variable and the sub-periods in the study, that is, pre-SAP, 1961-1985 SAP, SAP- 1986-1993, Post-SAP- 1986-2010 and ATA- 2011-2014.

3.6 Forecasting models

According to Nmadu, (2002), Nmadu,*et al.,* (2009) and Bivan, (2014), time series might not be linearly related to the series over the entire sample period, as the model tend to suggest. The models might be improved upon by dividing the data into different segments and applying different functional forms as suggested by the data rather than forcing the data to accept a particular form.

3.6.1 Forecasting Cassava yield in Nigeria

Based on visual observation of the time series data, the data on the yield of Cassava in Nigeria covering 1961-2014 (which was adequate in achieving the desired output or results of the analysis) was divided into four segments as shown in equations (16)-(19) hence the following trend function was suggested:

$$Y_t = \alpha_0 + \beta_0 t, \ t \leq 1974. \qquad (16)$$

$$Y_t = \alpha_1 + \beta_1 t, + \Theta_1 t^2, \ 1974 < t \leq 1984. \qquad (17)$$

$$Y_t = \alpha_2 + \beta_2 t, + \Theta_2 t^2, \ 1984 < t \leq 1999. \qquad (18)$$

$$Y_t = \alpha_3 + \beta_3 t, \ t > 1999. \qquad (19)$$

Where: Y_t= yield of Cassava in kg/ha in year t

t = trend

α, β and Θ= structural parameters to be estimated

Fuller (1969), Philip, (1990), Nmadu, (2002), Nmadu *et al.,* (2009) and Bivan, (2014), elucidated the desirable properties of the mean function, hence the restrictions of equations (16) -(19) and presented in equations (20) -(22)

$$\alpha_0 + \beta_0 R_1 = \alpha_1 + \beta_1 R_1 + \Theta_1 R_1^2. \quad (20)$$

$$\alpha_1 + \beta_1 R_2 + \Theta_1 R_2^2 = \alpha_2 + \beta_2 R_2 +. \Theta_2 R_2^2 \quad (21)$$

$$\alpha_2 + \beta_2 R_2 +. \Theta_2 R_2^2 = \alpha_3 + \beta_3 R_3 \quad (22)$$

Differentiation of equations (20) - (22) resulted in equations (23) - (25)

$$\beta_0 = \beta_1 + 2\Theta_1 R_1 \quad (23)$$

$$\beta_1 + 2\Theta_1 R_1 = \beta_2 + 2\Theta_2 R_2 \quad (24)$$

$$\beta_2 + 2\Theta_2 R_2 = \beta_3 \quad (25)$$

Where R's = joints of the different segments of the function.

In this study, R_1 =1974, while R_2 =1984 and R_3 =1999. There are ten parameters (α_0, α_1, α_2, α_3, β_0, β_1, β_2, β_3. Θ_0 and Θ_1), six restrictions equations (20)-(25) on the mean function thus reducing the number of parameters to be estimated to four. According to Philip, (1990), Nmadu, (2002, Nmadu *et al.,* (2009) and Bivan, (2014), the parameters on the latter models are retained.

The grafted or mean equation can now be obtained by substituting α_0, α_1, α_2 β_0, β_1, β_2 in equation (16) - (19). Given equation (26) - (29)

$$Y_t = \alpha_3 + \beta_3 t + \Theta_2 (2R_2 t - 2R_3 t + R^2{}_3 t - R^2{}_3 t) + \Theta_1 (2R_1 t - 2R_2 t + R^2{}_2 t - R^2{}_1 t),$$

$$t \leq 1974 \quad (26)$$

$$Y_t = \alpha_3 + \beta_3 t + \Theta_2 (2R_2 t + R_3^2 t - R_2^2) + \Theta_1 (R_2^2 - 2R_2 t + t^2) \; 1974 < t \leq 1984 \quad (27)$$

$Y_t = \alpha_3 + \beta_3 t + \Theta_2 (R_3^2 + 2R_3 t - t^2) \quad 1984 < t \leq 1999$ (28)

$Y_t = \alpha_3 + \beta_3 t, t > 1999.$ (29)

The above equation, (26)-(29), can therefore be formed into single equation for estimation in equation (30) in line with Philip, (1990) and Nmadu, (2002)

$Y_t = \mu_0 W_0 + \mu_1 W_1 + \mu_1 W_2 + U_{t.}$ (30)

Where $W_0 = 1, \psi t, \psi =$ for all

$W_1 = t, \psi t$

$W_2 = (2R_2^2 t - 2R_3^2 + R_3^2 - R_3^2) \quad \psi \quad t \leq 1974$

$= (2R_2 t + R_3^2 - R_2^2), \quad \psi \quad 1974 < t \leq 1984$

$= (R_3^2 + 2R_3 t - t^2), \quad \psi \quad 1984 < t \leq 1999$

$W_0 = 0, \quad \psi \quad t > 1999$

$W_3 = (2R_1 t - 2R_2 t + R_3^2 - R_2^2 - R_1^2) \quad \psi \quad t \leq 1974$

$= (R_2^2 - 2R_2 t - t^2), \quad \psi \quad 1974 < t \leq 1984$

$W_3 = 0 \quad \psi \quad 1984 < t \leq 1999$

$W_3 = 0 \quad \psi \quad t > 1999$

U_1 = error term assumed to be well behaved

3.6.2 Forecasting Cassava Hectarage in Nigeria

The data on the output of Cassava in Nigeria covering 1961-2014 was divided into four segments based on visual observation as shown in equations (31) -(34). The difference between forecasting yield and hectarage was the division of their respective segments which are not the same.

$$A_t = \alpha_0 + \beta_0 t, \; t \leq 1980. \tag{31}$$

$$A_t = \alpha_1 + \beta_1 t, + \Theta_1 t^2, \; 1980 < t \leq 1990. \tag{32}$$

$$A_t = \alpha_2 + \beta_2 t, + \Theta_2 t^2, \; 1990 < t \leq 2000. \tag{33}$$

$$A_t = \alpha_3 + \beta_3 t, \; t > 2000. \tag{34}$$

Where: A_t= Cassava hectarage in '000 hectares in year t

t = trend

α, β and Θ= structural parameters estimated.

The restrictions of equations (31) - (34) and presented in equations (35) - (40)

$$\alpha_0 + \beta_0 R_1 = \alpha_1 + \beta_1 R_1 + \Theta_1 R_1^2. \tag{35}$$

$$\alpha_1 + \beta_1 R_2 + \Theta_1 R_2^2 = \alpha_2 + \beta_2 R_2 +. \Theta_2 R_2^2 \tag{36}$$

$$\alpha_2 + \beta_2 R_2 +. \Theta_2 R_2^2 = \alpha_3 + \beta_3 R_3 \tag{37}$$

$$\beta_0 = \beta_1 + 2\Theta_1 R_1 \tag{38}$$

$$\beta_1 + 2\Theta_1 R_1 = \beta_2 + 2\Theta_2 R_2 \tag{39}$$

$$\beta_2 + 2\Theta_2 R_2 = \beta_3 \tag{40}$$

Where R's = joints of the different segments of the function.

In this study, R_1 =1980, while R_2 =1990 and R_3 =2000. There are ten parameters (α_0, α_1, α_2, α_3, β_0, β_1, β_2, β_3, Θ_0 and Θ_1) six restrictions equations (35)-(40) on the mean function thus reducing the number of parameters to be estimated to four. The parameters on the latter models are retained.

The grafted or mean equation can now be obtained by substituting α_0, α_1, α_2 β_0, β_1, β_2 in equation (31) - (34). Given equation (41) -(44)

$A_t = \alpha_3 + \beta_3\, t + \Theta_2 (2R_2t - 2R_3\, t + R^2{}_3\, t - R^2{}_3\, t) + \Theta_1(2R_1t - 2R_2\, t + R^2{}_2\, t - R^2{}_1\, t)$,

$t \leq 1980$ (41)

$A_t = \alpha_3 + \beta_3\, t + \Theta_2 (2R_2t + R_3^2\, t - R_2^2) + \Theta_1 (R_2^2 - 2R_2t + t^2)$, $1980 < t \leq 1990$ (42)

$A_t = \alpha_3 + \beta_3\, t + \Theta_2 (R_3^2 + 2R_3t - t^2)$ $1990 < t \leq 2000$ (43)

$A_t = \alpha_3 + \beta_3\, t$, $t > 2000$. (44)

The above equation, (41)-(44), can therefore be formed into single equation for estimation in equation (45) in line with Philip, (1990) and Nmadu, (2002).

$A_t = \mu_0 W_0 + \mu_1 W_1 + \mu_1 W_2 + U_{t.}$ (45)

Where W_0 = $1, \psi\, t, \psi$ = for all

W_1 = $t, \psi\, t$

W_2 = $(2R_2^2t - 2R_3^2 + R_3^2 - R_3^2)$ ψ $t \leq 1980$

= $(2R_2t + R_3^2 - R_2^2)$, ψ $1980 < t \leq 1990$

= $(R_3^2 + 2R_3t - t^2)$, ψ $1990 < t \leq 2000$

W_0 = 0, ψ $t > 2000$

W_3 = $(2R_1t - 2R_2t + R_3^2 - R_2^2 - R_1^2)$ ψ $t \leq 1980$

= $(R_2^2 - 2R_2t - t^2)$, ψ $1980 < t \leq 1990$

W_3 = 0 ψ $1990 < t \leq 2000$

W_3 = 0 ψ $t > 2000$

U_1 = error term assumed to be well behaved

3.6.3 Forecasting Cassava production in Nigeria

The data for Cassava production in Nigeria used was from (1961-2014), and based on visual observation from figure it was indicated that the data was divided into different segments as the trend equation below:

$$Q_t = \alpha_0 + \beta_0 t,\ t \leq 1970. \tag{46}$$

$$Q_t = \alpha_1 + \beta_1 t, + \Theta_1 t^2,\ 1970 < t \leq 1990. \tag{47}$$

$$Q_t = \alpha_2 + \beta_2 t, + \Theta_2 t^2,\ 1990 < t \leq 2000. \tag{48}$$

$$Q_t = \alpha_3 + \beta_3 t,\ t > 2000. \tag{49}$$

Where: Q_t= output of Cassava in '000 metric tonnes in year t

t = trend

α, β and Θ= structural parameters estimated

The restrictions of equations (46) - (49) and presented in equations (50) - (55)

$$\alpha_0 + \beta_0 R_1 = \alpha_1 + \beta_1 R_1 + \Theta_1 R_1^2. \tag{50}$$

$$\alpha_1 + \beta_1 R_2 + \Theta_1 R_2^2 = \alpha_2 + \beta_2 R_2 +.\ \Theta_2 R_2^2 \tag{51}$$

$$\alpha_2 + \beta_2 R_2 +.\ \Theta_2 R_2^2 = \alpha_3 + \beta_3 R_3 \tag{52}$$

$$\beta_0 = \beta_1 + 2\Theta_1 R_1 \tag{53}$$

$$\beta_1 + 2\Theta_1 R_1 = \beta_2 + 2\Theta_2 R_2 \tag{54}$$

$$\beta_2 + 2\Theta_2 R_2 = \beta_3 \tag{55}$$

Where R's = joints of the different segments of the function.

In this study, R_1 =1970, while R_2 =1990 and R_3 =2000. There are ten parameters (α_0, α_1, α_2, α_3, β_0, β_1, β_2, β_3. Θ_0 and Θ_1), six restrictions equations (50)-(55) on the mean function thus reducing the number of parameters to be estimated to four. The parameters on the latter models are retained.

The grafted or mean equation can now be obtained by substituting α_0, α_1, α_2 β_0, β_1, β_2 in equation (46) - (49). Given equation (50) - (53)

$$Q_t = \alpha_3 + \beta_3 t + \Theta_2 (2R_2t - 2R_3 t + R^2{}_3 t - R^2{}_3 t) + \Theta_1 (2R_1t - 2R_2 t + R^2{}_2 t - R^2{}_1 t),$$

$$t \leq 1970 \qquad (56)$$

$$Q_t = \alpha_3 + \beta_3 t + \Theta_2 (2R_2t + R_3^2 t - R_2^2) + \Theta_1 (R_2^2 - 2R_2t + t^2) , 1970 < t \leq 1990 \qquad (57)$$

$$Q_t = \alpha_3 + \beta_3 t + \Theta_2 (R_3^2 + 2R_3t - t^2) \; 1990 < t \leq 2000 \qquad (58)$$

$$Q_t = \alpha_3 + \beta_3 t, t > 2000. \qquad (59)$$

The above equation, (56)-(59), can therefore be formed into single equation for estimation in equation (60) in line with Philip, (1990) and Nmadu, (2002).

$$Q_t = \mu_0 W_0 + \mu_1 W_1 + \mu_1 W_2 + \mu_1 W_3 + U_t. \qquad (54)$$

Where $W_0 = 1, \psi\, t, \psi$ = for all

$W_1 = t, \psi\, t$

$W_2 = (2R_2^2t - 2R_3^2 + R_3^2 - R_3^2) \quad \psi \quad t \leq 1970$

$= (2R_2t + R_3^2 - R_2^2), \quad \psi \quad 1970 < t \leq 1990$

$= (R_3^2 + 2R_3t - t^2), \quad \psi \quad 1990 < t \leq 2000$

$W_0 = 0, \quad \psi \quad t > 2000$

$W_3 \quad = (2R_1t - 2R_2t + R_3^2 - R_2^2 - R_1^2) \quad \psi \quad t \leq 1970$

$= \quad (R_2^2 - 2R_2t - t^2), \quad \psi \quad 1970 < t \leq 1990$

$W_3 \quad = 0 \quad \psi \quad 1990 < t \leq 2000$

$W_3 \quad = 0 \quad \psi \quad t > 2000$

$U_1 \quad = \quad$ error term assumed to be well behaved

Equations (30), (45) and (60) served as the mean equations; they are continuous with the various restrictions given above.

3.7 Cassava supply response using adaptive expectation hypothesis

The Nerlovian adaptive expectations hypothesis (Nerlove, 1956, 1958a) used in this study was two-equation model as given below, this is due to the fact that based on assumption that farmers form planting decisions of what and how much to produce based on the past price series. Mostly, farmers are hardly aware of the prices of their produce that will prevail at the time of supply during the periods of planting.

$$A_t = \alpha_o + \alpha_1 P_t^e + \alpha_2 R_t + \alpha_3 DU_t + \alpha_4 RD_t + \alpha_5 TI_t + \alpha_6 TM_t + \alpha_7 HM_t + \alpha_8 PF_{t-1} + U_t. \quad (61)$$

$$P_t^e = P^e_{t-1} + \beta_t (P_{t-1)} - P^e_{t-1}). \quad (62)$$

$\beta_t < 0 < 1$

t = Year from 1961 to 2014

At = actual Cassava hectarage in year t

P_{t-1}= price of raw cassava in naira/metric tonne in previous year

$P^e t$ = expected price of raw cassava in naira/metric tonne in year t

Rt = amount (quantity) of rainfall in mm in year t

RDt = number of days rain fell in year t

DUt = period of raining season in year t (duration of raining season)

Tit = minimum temperature in year t

TMt = maximum temperature in year t

PFt = price of fertilizer in naira/metric tonne in year t

HMt = relative humidity in year t

β_t = adaptive expectation coefficient in year t

α's, b's = structural parameters to be estimated

U_t = error term assumed to be well behaved

In this study, it was proposed that the coefficient of Nerlovian model is a function of other exogenous factors (Joshua, 2010 and Bingxin, *et al.* 2012) since the original Nerlovian model (Nerlove, 1956, 1958a) assumed that the coefficient is invariant with trend. The equation is as follows:

$$\beta_t = b_0 + b_1 * R_t + b_2 * DU_t + b_3 * RD_t + b_4 * Ti_t + b_5 * TM_t + b_6 * HM_t + b_7 * PFt1 \quad (63)$$

Where a and b's are structural parameters estimated and other variables were previously defined.

3.8 Cassava supply response using partial adjustment hypothesis

There is difference between adaptive hypothesis and the partial adjustment hypothesis. The only difference is the basic assumption about price. In partial adjustment, it is assumed that the price information is available to the farmers but his planned hectarage is not achieved based on that, this study was able to find out the constraints of Nigerian cassava farmers towards achieving the planned cassava hectarage. Some of these constraints are inconsistency of the government policy in agriculture, inadequate incentives and illiteracy/conservative of nature of the farmers. The basic hypothesis was two-model equation give as:

Specification of partial adjustment model

$A^*_t = \alpha_o+\alpha_1(Pt,1)+\alpha_2\ (Yt,1)+\alpha_3(Wt,1)+\alpha_4ON_t+\alpha_5(CSt,1)+\alpha_6(PFt,1)+U_t$ (64)

$A_t = (At,1) + (1-\lambda_t)(A^*_t - (At,1))$ (65)

Where:

t = Year from 1961 to 2014

At = actual Cassava hectarage in year t

A*t = planned Cassava hectarage in year t

Yt = Cassava yield kg/ha in year t

ONt = number of days from Jan. 1 to when rain commenced in year t

CSt = number of days from Jan. 1 to when rain ceased in year t

PFt = price of fertilizer in naira/metric tonne in year t

Wt = wage rate in naira/man-day in year t

α's, b's = structural parameters to be estimated

λ_t = partial adjustment coefficient in year t

U_t = error term assumed to be well behaved

The (Nerlove, 1958), adjustment coefficient was built based on the assumption that the coefficient of adjustment is said to be invariant with trend. Usually, in a dynamic environment the adjustment process might be influenced by other factors as such farmers are expected to have flexible plans such that when better information becomes available, they can be incorporated into plan, hence the need for the following equation:

$\lambda_t < 0 < 1$

$\lambda_t = b_0+b_1Y_t+b_2(Wt,1)+b_3ON_t+b_4(CSt,1)+b_5(PFt,1)$ (66)

Where a and b's are structural parameters estimated and other variables were previously defined

3.8 Elasticity of Cassava farmers supply response

Elasticity of supply is the degree of responsiveness of supply to changes in prevailing market prices and other factors over a period of time, (Shittu, Ajuwon and kehinde 2012; Udu and Agu, 2013 and Anyanwuocha, 2013). Supply is usually more price elastic, the longer the time period that a supplier is allowed to adjust its production level (s). Supply is likely to be price inelastic in the short run because it may be difficult for farmers to expand output and to increase their use of factors of production such as land and capital. Elasticity of hectarage response is commonly measured using the constant elasticity of substitution (CES) method (Johnston, 1991). The method is a two model equation given as:

$$A^{*}_{t} = aP^{\beta}_{t}. \tag{67}$$

$$\frac{At}{At-1} = \left(\frac{At}{At}\right)^{(1-\lambda)} e^{Ut}. \tag{68}$$

All variables are previously defined.

Equation (67) is substituted into equation (68) and re-arranged to obtain:

$$A_t = a^{1-\lambda} P_t^{\beta(1-\lambda)} A_{t-1}^{\lambda} eU_t \tag{69}$$

In order to linearise equation (69), natural logarithm of it will be obtained:

$$\ln A_t = (1-\lambda) \ln a + \beta(1-\lambda) \ln P_t + \lambda \ln A_{t-1} + U_t \tag{70}$$

Equation (70) is a double-log model (Cobb-Douglass) hence the elasticity is the estimation of the parameters directly. Therefore, the short run elasticity of Cassava is given as:

$$\dot{\eta}_s = \beta\,(1-\lambda) \tag{71}$$

The long run elasticity of Cassava supply was formed by dividing equation 71 by (1-λ) which is given as:

$$\dot{\eta}_s = \frac{\beta(1-\lambda)}{(1-\lambda)} = \beta \tag{72}$$

3.10 Stationarity/ Unit Root Test

Augmented Dickey Fuller (ADF) was employed to test (unit root test) for the presence of the unit root (evidence of non-stationary). The advantage of the method lies on its robustness to handle both first order and higher order autoregressive processes, Abu *et.al.,* (2015). The model for stationary test can be presented as follows:

$$\Delta Y_t = a + Y_{t-1} + \Psi T + \sum_{k=0}^{N} \beta k \, \Delta Y_{t-1} + U_t \qquad (73)$$

Where:

Δ = first difference operator

Y_t = crops yield series being investigated for stationarity

$$\Delta P_t = a + P_{t-1} + \Psi T + \sum_{k=0}^{N} \beta k \, \Delta P_{t-1} + U_t. \qquad (74)$$

Where:

P_t = crops price series being investigated for stationarity

T = time or trend variable

a, Ψ, β = parameters to be determined

U_t = error term

Y_t or P_t has unit root if the regression β = 0, otherwise the unit root does not exist (Iganiga and Unemhilin, 2011; Akintunde, *et. al.,* 2013 and Abu *et.al.,* 2015).

In order to ensure that the error term (ut) in the test model is empirically white noise, the optimum lag order (N) will be chosen where Akaike information criteria (AIC) is minimum within the lag range dictated by $\frac{1}{2}$ rule(K_{max}.= $(12\,\frac{T}{100})^{0.25}$

Where T = sample size

K_{max} = maximum lag order permissible for unit root test

Furthermore, the significance of coefficient β will be tested against null hypothesis of unit root based on the computed ADF and tabulated Mackinnon critical values.

Decision rule: if the computed ADF statistic is greater than the critical value at specified level of significance, then the null hypothesis of unit root is accepted otherwise it is rejected.

3.10 Method of estimation

The mean trend values of hectarage, yield and output of cassava covering the period 1961–2014 classified or analysed as the pre-SAP, Structural Adjustment Programme (SAP), post-

SAP periods and Agricultural Transformation Agenda. All of the analyses were classified by the SAP stages to examine whether the major policy instrument has any influence on the performance of cassava. The 1961–1985 periods depict the pre-SAP stage; the 1986–1993 periods depict the main SAP implementation stage, the 1994–2010 periods depict the post-SAP stage and 2011-104 represent ATA periods. Grafted polynomial models were used in carrying out the forecast on the hectarage (‘000’ hectares), yield (kg/ha) and output (‘000’ metric tonnes) of cassava in Nigeria using observed data from 1961 to 2014 which was obtained from Food and Agricultural Organisation (F.A.O.). Ordinary Least Square technique was applied to equations 24, 39 and 54 for forecast evaluation in order to assess their predictive performance.

Nerlove model was employed in the estimation of supply response. Nerlove model was constructed to handle two dynamic processes namely, partial adjustment and adaptive expectation. Partial adjustment model was used to estimate the level and speed of adjustment policy incentives ($Q_t - Q_{t-1} = \gamma (Q_t^e - Q_{t-1})$, $\gamma < 0 < 1$ equation 2), the coefficient of partial adjustment (γ), Q_t - Q_{t-1} is the actual change in output and (Q_t^e - Q_{t-1}) is the desired change in output. This means that the actual change in output in any given time period t is some fraction γ of the desired change for the period. If $\gamma = 1$, it means that the actual output is equal to the desired output, that is, actual output adjusts to the desired output instantaneously in the same time period. However, if $\gamma = 0$, it means that there is no change since actual output at time t is the same as that observed in the previous time period. Typically, γ is expected to lie between these extremes since adjustment to the desired output is likely to be constrained by policy lags.

Specification of a model that explains how price expectations are formed based on differences between actual and past prices assumes:

(P_t^e - P_{t-1} = λ (P_{t-1} - P_{t-1}), λ<0<1 equation 3) Where, λ is the adaptive expectations coefficient. This means that expectations about the price level are revised by farmers by a fraction λ of the gap between the price level observed in the current period and what its anticipated value had been in the previous period. If λ = 1, it means that expectations are realized immediately and fully, that is, in the same time period. If, on the other hand, λ = 0, it means that expectations are static, that is, conditions prevailing today will be maintained in all subsequent periods. The r-software package was used in analysis of the data.

Augmented Dickey Fuller technique was applied to the data in order to test the stationarity of the data, the results show that annual rainfall, number of rain days in a year, duration of rain in a year, number of days from Jan. 1 when rain commenced in year, number of days from Jan. 1 when rain ceased in a year, minimum temperature, maximum temperature, average temperature were all stationary at level 1(0), that is they are integrated at order of zero. The data of cassava hectarage, cassava yield, cassava output, and cassava price, prices of fertilizer and exchange rate of naira to U.S dollars in a year were stationary at first differencing 1(1).

CHAPTER FOUR

4.0. RESULTS AND DISCUSSON

The results of the stationarity test, trend of cassava hectarage, yield and output in Nigeria from 1961-2014, grafted polynomial models of cassava hectarage, yield and output in Nigeria from 1961-2014, forecast of cassava hectarage, yield and output using grafted polynomial models (2015-2035), cassava supply response using adaptive expectation hypothesis, cassava supply response using partial adjustment hypothesis, forecast of cassava supply response using the estimated models (2015-2064), and cassava economy in Nigeria (1961-2014) are presented in this chapter.

4.1 Trend of cassava hectarage, yield and output in Nigeria from 1961 to 2014

Table 4.1 presents the compound growth rate computed from the exponential growth equation of cassava production in Nigeria. The result shows that the mean growth rate of cassava hectarage was 8.3% which translated to negative yield of -23% and 7.3% growth rate of cassava output. The increase in output might be as a result of expansion of hectarage under cultivation. The entire periods under study shows an encouraging result on the hectarage, yield and output with growth rates of 4.1%, 0.1% and 4.2% respectively. It was observed that before the introduction of Structural Adjustment Programme (SAP), the hectarage under cultivation increase by 1.8% which eventually led to increase in yield by 0.2% and output by 2.0%. This result is in agreement with Nmadu *et tal.* 2015, that the expansion in area planted to yam and cassava was the main component of increased production. Although, cassava was not a traded commodity during Agricultural marketing board (pre-SAP) period, but there was positive increase in growth rate of cassava production in Nigeria. This development was due to the establishment of the national and international collaborative cassava development programme in 1970 which made national and international research institutions became

Table 4.1 Compound Growth rate of cassava production computed using the exponential coefficients

variable	hectarage	Yield	output
Entire periods	4.0713	0.1181	4.1941
Pre-SAP	1.8019	0.2222	2.0270
SAP	15.9031	-0.9645	0.0030
Post SAP	1.6068	0.0816	27.2476
ATA	18.3533	-11.6856	4.5229
Mean	8.34658	-2.44380	7.59892

Source: Computer result output, 2019

actively involved in cassava improvement and development in Nigeria and eventually led to the development of new improved varieties of cassava. It was observed that the yield of cassava during the SAP period declined and output was stagnant despite large expansion of cassava hectarage under cultivation, most likely due to outdated production technology as well as low management skills. The result under SAP period shows the growth rate of hectarage, yield and output to be 16%, -1.0% and 0.0% respectively. However, there was an improvement in the growth rate of the hectarage, yield and output after SAP period. The growth rate of cassava hectarage increased by 2.0%, yield increase by 0.1% and output increase by 27.2%. The improvement recorded in cassava production was due to presidential initiative policies introduced after SAP which led to the establishment of Cassava Multiplication Programme (CMP) and Root and Tuber Expansion Programme (RTEP) with the objective of enhancing national food self-sufficiency, improve rural households' food security and income for poor farmers within the cassava producing States of Nigeria, (Iyagba and Anyanwu, 2012). Agricultural Transformation Agenda (ATA) was another policy established in 2011. The result of this study under ATA period shows a progressive growth rate of hectarage and output but with a declining rate of growth of yield. Hectarage grew by 18.4%, while yield decrease by -12.0% and output increase by 5%, the declining yield may be due to non-adoption of modern technology and conservative nature of the famers. The increase in hectarage and output under ATA was probably due to famers' accessibility to agro-inputs through voucher system of distribution.

Table 4.2 shows the number of years it will take to double the rate of growth of cassava time series (Doubling time). The result shows that it will take mean of 8years (that is by year 2022) to double the rate of growth of cassava hectarage based on the current trend, this translated to high cassava output which will take 7yeras to double the growth rate (that is by year 2021) and the doubling time for yield indicated that cassava production technology is as old as 1992. This confirms the assertion that most policy reforms in the past were translated to ''hectarage expansion", meaning that more land is put under cultivation which leads to over-utilization of labour and low efficiency of the other inputs (Nmadu, *et tal.,* 2015). The result also shows that pre-SAP and post-SAP periods will take very long time to double the growth rate of cassava hectarage and yield.

Table 4.2 Doubling time for cassava production in Nigeria

variables	hectarage	yield	output

Entire period	13.5092	465.7070	13.1136
Pre-SAP	30.5233	247.5247	27.1336
SAP	3.4584	-57.0243	18,3333.333
Post-SAP	34.2295	674.0196	2.0185
ATA	2.9967	-4.7066	12.1603
Mean	8.3466	-22.5059	7.3110

Source: Computer result output, 2019

Table 4.3 shows that the hectarage, output and yield exhibited significant and positive trends in the entire period for both hectarage and output except for the cassava yield. During this period the coefficient of the trend variable was significantly different from zero at 1% for hectarage and output and yield non-significant. Table 4.3 also presents the acceleration, deceleration and stagnation of cassava growth rate, the results show that over the entire period, the output and hectarage accelerated with the exception of cassava yield which was decelerated. The pre-SAP period shows that hectarage was stagnant which led to deceleration of yield and output while during SAP period there was acceleration of cassava hectarage but yield declined and output remained stagnant. Post-SAP period shows accelerated growth rate for yield and output but there was a declined in the growth rate of hectarage, probably due better farming methods and adoption of technology. The ATA period was not different from other sub-periods; the result under ATA period indicated accelerated output with stagnant growth rate of hectarage and yield. . During all the sub-periods acceleration was observed to be highest compare to deceleration and stagnation for cassava acreage. The implication of this is that, the policy presentation for cassava translated to sustained increase in growth rate.

Table 4.3 Quadratic coefficients and nature of growth of cassava production in Nigeria

variable	hectarage	Yield	output
Entire periods	0.000408*** (A) (0.000108)	-0.00019*** (D) (0.00006)	0.000537*** (A) (0.000121)
Pre-SAP	-0.000011 (S) (0.000241)	-0.00048** (D) (0.000298)	-0.00058* (D) (0.000227)

SAP	0.003493*** (A)	-0.00078* (D)	0.002718 (S)
	(0.008147)	(0.003683	(0.00523)
Post SAP	-0.00175* (D)	0.001957*** (A)	0.000203*** (A)
	(0.000732)	(0.000641	(0.000842)
ATA	-0.09714 (S)	0.108884	0.011855*** (A)
	(0.043558)	(0.000206)	(0.043352)

Values in parenthesis are standard error, * 1%, ** 5%, * 10% significant levels.**

Source: Computer result output, 2019

4.1.1 Stationarity Test

To avoid spurious results of regression; stationarity test was conducted on the data of cassava hectarage, cassava yield, cassava output, cassava price, annual rainfall, number of rain days in a year, duration of rain in a year, number of days from Jan. 1 when rain commenced in year, number of days from Jan. 1 when rain ceased in a year, minimum temperature, maximum temperature, average temperature, prices of fertilizer and exchange rate of naira to U.S dollars in a year. The results of the stationarity test were presented in Table 4.4. the results show that annual rainfall, number of rain days in a year, duration of rain in a year, number of days from Jan. 1 when rain commenced in year, number of days from Jan. 1 when rain ceased in a year, minimum temperature, maximum temperature, average temperature were all stationary at level 1(0), that is they are integrated at order of zero. The data of cassava hectarage, cassava yield, cassava output, and cassava price, prices of fertilizer and exchange rate of naira to U.S dollars in a year were stationary at first differencing 1(1). The null hypothesis states that there was no unit root in the data while the alternative hypothesis states that there was a unit root in the data. Since the decision rule states that: if the computed Augmented Dickey Fuller (ADF) statistic is greater than the critical value at specified level of significance, then the null hypothesis of unit root is accepted otherwise it is rejected. The null hypothesis was accepted that there was no evidence of unit root. The result was computed at 5% level of significance

Table 4.4. Estimates of staionarity / unit root test

Variable	observation	lag	ADF	t-statistics (critical value)	order level	p-value
Annual rainfall	54	0	4.945	4.945 (2.928)**	1(0)	0.000
Rain days	54	0	4.410	4.410 (2.928)**	1(0)	0.000
Duration of rain	54	0	6.642	6.642 (2.928)**	1(0)	0.000
Onset of rain	54	0	7.664	7.664 (2.928)**	1(0)	0.000
Cessation of rain	54	0	4.018	4.018 (2.928)**	1(0)	0.000
Min temperature	54	0	7.280	7.280 (2.928)**	1(0)	0.000
Max temperature	54	0	4.177	4.177 (2.928)**	1(0)	0.000
Average temperature	54	0	7.278	7.278 (2.928)**	1(0)	0.000
Cassava hectarage	53	0	5.378	5.378 (2.928)**	1(1)	0.000
Cassava yield	53	0	7.757	7.757 (2.928)**	1(1)	0.000
Cassava output	53	0	7.555	7.555 (2.928)**	1(1)	0.000
Cassava price	53	0	12.173	12.173 (2.928)**	1(1)	0.000
Fertilizer price	53	0	8.927	8.927	1(1)	0.000

Exchange rate	53	0	6.609	(2.928)** 6.609 (2.928)**	1(1)	0.000

Source: **Computer result output, 2019.**

4.2 Grafted polynomial models for cassava hectarage

In this section, the results of all the forecasting models used for the estimation of cassava hectarage are presented.

4.2.1 Estimates of Polynomial models, for cassava hectarage

Table 4.5 presents the estimates of the grafted models (with and without joint points), linear, semi-log and growth models. Series 3 of the estimates of the polynomial model without joint points is significance at 1% while series 4, 5, 6 and 7 of the model with joint points were all significant at 1% and series 3 of the same model with joint points is significant at 10%. This indicates that the polynomial model with joint points gives the best estimates. It also shows that polynomial models are better used in forecasting than the linear and semi log. This finding is in conformity with the finding of Bivan *et al*. (2013), which investigated the performance of linear and grafted polynomial functions in forecasting sorghum production in Nigeria. The resulting mean (grafted) function provided more reliable ex-post forecasts of sorghum production than those yielded from merely fitting a linear function to the data used. The researchers concluded that sorghum production trend predicted with the grafted function is closer to the observed trend when compared to that of the linear function because it resulted in smaller differences. They affirmed that the grafted function incorporated the major observed local trends in the forecasting framework.

Variable	**Without Knots**	**With Knots**	**Linear**	**Semilog**	**Growth**
	(1)	(2)	(3)	(4)	(5)
(Intercept)	78.445 **	74.988**	-18.615	-147.788 *	13.311
	(2.644)	(2.184)	(2.022)	(5.537)	(0.053)
bs(niz[, 1], knots = NULL)1	19.029				
	(7.707)				
bs(niz[, 1], knots = NULL)2	50.266				
	(5.043)				
bs(niz[, 1], knots = NULL)3	50.876 ***				
	(4.125)				
bs(niz[, 1], knots = c(21, 31, 41, 50))1		34.046			
		(4.836)			
bs(niz[, 1], knots = c(21, 31, 41, 50))2		-13.720			
		(3.172)			
bs(niz[, 1], knots = c(21, 31, 41, 50))3		98.652 **			
		(3.516)			
bs(niz[, 1], knots = c(21, 31, 41, 50))4		359.573 ***			
		(3.388)			
bs(niz[, 1], knots = c(21, 31, 41, 50))5		175.938 ***			
		(4.093)			
bs(niz[, 1], knots = c(21, 31, 41, 50))6		514.363***			
		(3.964)			

bs(niz[, 1], knots = c(21, 31, 41, 50))7		662.429 ***			
		(3.797)			
niz[, 1]			88.599***		0.039
			(6.397)		(0.001)
log(niz[, 1])				122.519 ***	
				(1.747)	
N	54	54	54	54	54
R^2	0.896	0.962	0.786	0.486	0.915
Log Likelihood	-785.273	-757.686	-804.845	-828.593	13.167
AIC	1580.546	1533.372	1615.691	1663.186	-20.335

Table 4.5: Estimates of the forecasting models for cassava hectarage

*****1% significant level, **5% level of significance *10% significant level**

Values in parenthesis are computed t-values

Source: Computer result output, 2019.

4.2.2. Grafted polynomial models showing the cut points and tracing path of the data for cassava hectarage

Figure 4.1, shows the historical path of the data, it was observed that the spline model with joint (knots) points better traces the historical path of the data while the spline without joint points was a little bit closer to the trend of the observed data. The linear and semi log models are completely at variance with the observed data which means they cannot give the best result for forecasting, The cut points were derived from the observed data, the first cut point (21) was obtained from 1980 data, the second cut point (31) was obtained from 1990 data, the third cut point (41) was obtained from year 2000 and the fourth cut point (50) was obtained from 2009. It was also observed in figure 4.2 that the smoothing spline was included in the diagram and it gives the best result, it exactly traces the path of the observed data. It implies that the smoothes spline always tries to smoothing the noise of the data. From these diagrams (figures 4.1 and 4.2), spline with joint points and the smoothing spline are expected to give better results in the estimation, this is in conformity with the findings of Odedukun, (2014), which shows grafted polynomial models to be the best model in forecasting

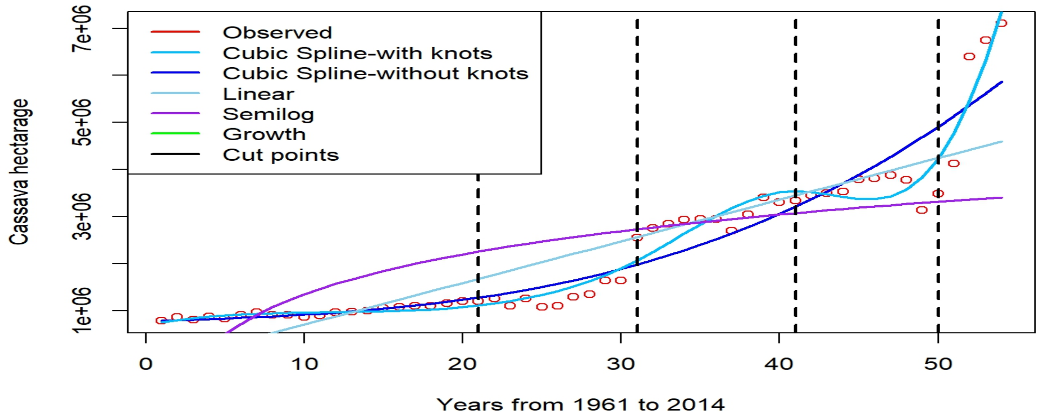


Figure 4.1: Cassava hectarage 1961 to 2014 showing the cut points.

Source: Computer result output, 2019.

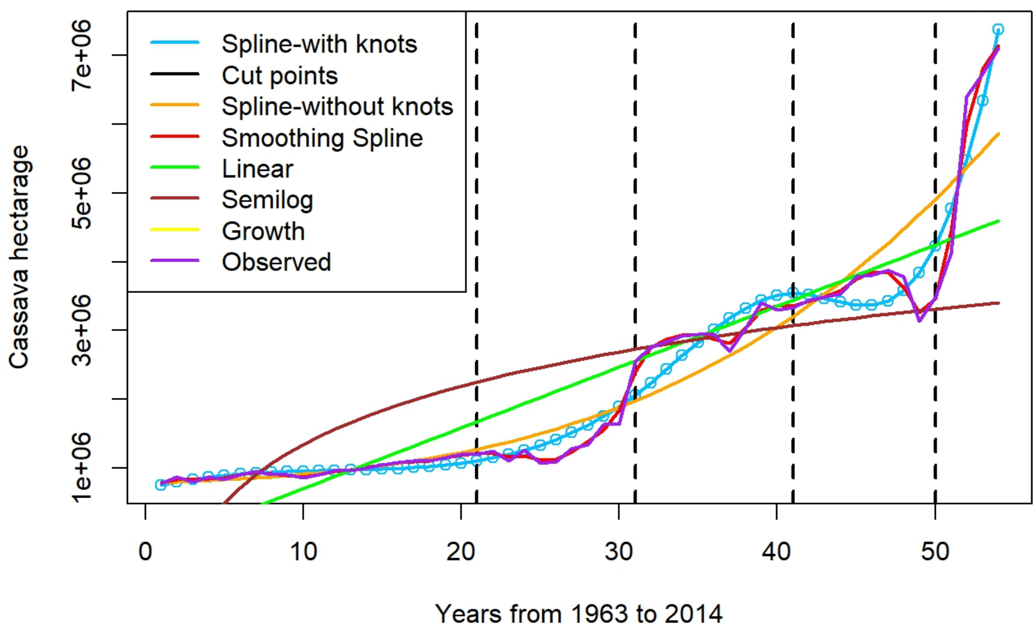


Figure 4.2: Cassava hectarage 1961 to 2014 showing the tracing path of the models.

Source: Computer result output, 2019.

Table 4.6 shows the goodness of fit properties and turning points of the models, the spline models with and without cuts are adjudged to be the best compared to cubic, linear, semi-log and growth models because of the low level of Mean error (ME), Mean absolute error (MAE), Mean percentage error (MPE), Mean Squared error (MSE), Root mean of the squared error (RSME), Theil's inequality coefficient (U) and high level of R-square (R^2,) although cubic spline model has the least error but zero R-square and Adjusted R-square which meams automatically is not fit to be used in estimation or forecasting..

Table 4.6: Goodness of fit properties and turning points of the models

variables	Spline-with cuts	Spline-without cuts	Cubic	Linear	Semilog	Growth
ME	0.8600	-0.1700	0.3000	0.5200	0.8600	23.0000
MAE	32.0000	21.0000	5.2000	48.0000	80.0000	230.0000
MPE	-0.2700	-0.1200	1.7000	-0.1400	-1.5000	10.0000
MAPE	12.000	9.000	2.3000	31.000	53.000	100.000
MSE	25.0000	9.0000	0.8500	52.0000	120.0000	75.0000
RMSE	50.0000	30.0000	9.2000	72.0000	110.0000	270.0000
U	0.1300	7.8000	2.4000	0.1900	0.2900	0.7100
Turning points	13.000	18.000	9.000	13.000	13.000	13.000
R-square	96.000	89.000	0.000	78.000	48.000	91.000
Adjusted R-square	96.000	89.000	0.000	78.000	48.000	91.000

ME= Mean error, MAE= Mean absolute error, MPE= Mean percentage error, MSE=Mean Squared error, RSME= Root mean of the squared error, U = Theil's inequality coefficient

Source: Computer result output, 2019.

4.3 Mean forecast of the cassava hectarage using grafted polynomial models, 2015-2035.

The results of the forecasts are presented in figure 4.3 and 4.4. The results show consistency with the estimated results and the expectation about the future. However, a careful examination shows that the spline models with joint points are generally in a family of good forecasting models. The forecast shows slowly but continuous increase in cassava hectarage by both the cubic spline, spline with joint points and spline without joint points. Figure 4.4 shows cubic spline exhibiting kink features which is not good in forecasting, while spline without cut shows monotonic rise or increase in hectares allocated to cassava in Nigeria. Spline with cuts shows quadratic movement in the hectare allocated to cassava production. It was also observed that by the year 2035, the hectarage allocated to cassava production in Nigeria will increase to the maximum of about 11,200,000 hectares. This is not surprising, since land has competitive demand, since the population of the country is increasing there is possibility of allocating land meant for cassava production to other uses such as residential and industrial purposes in future.

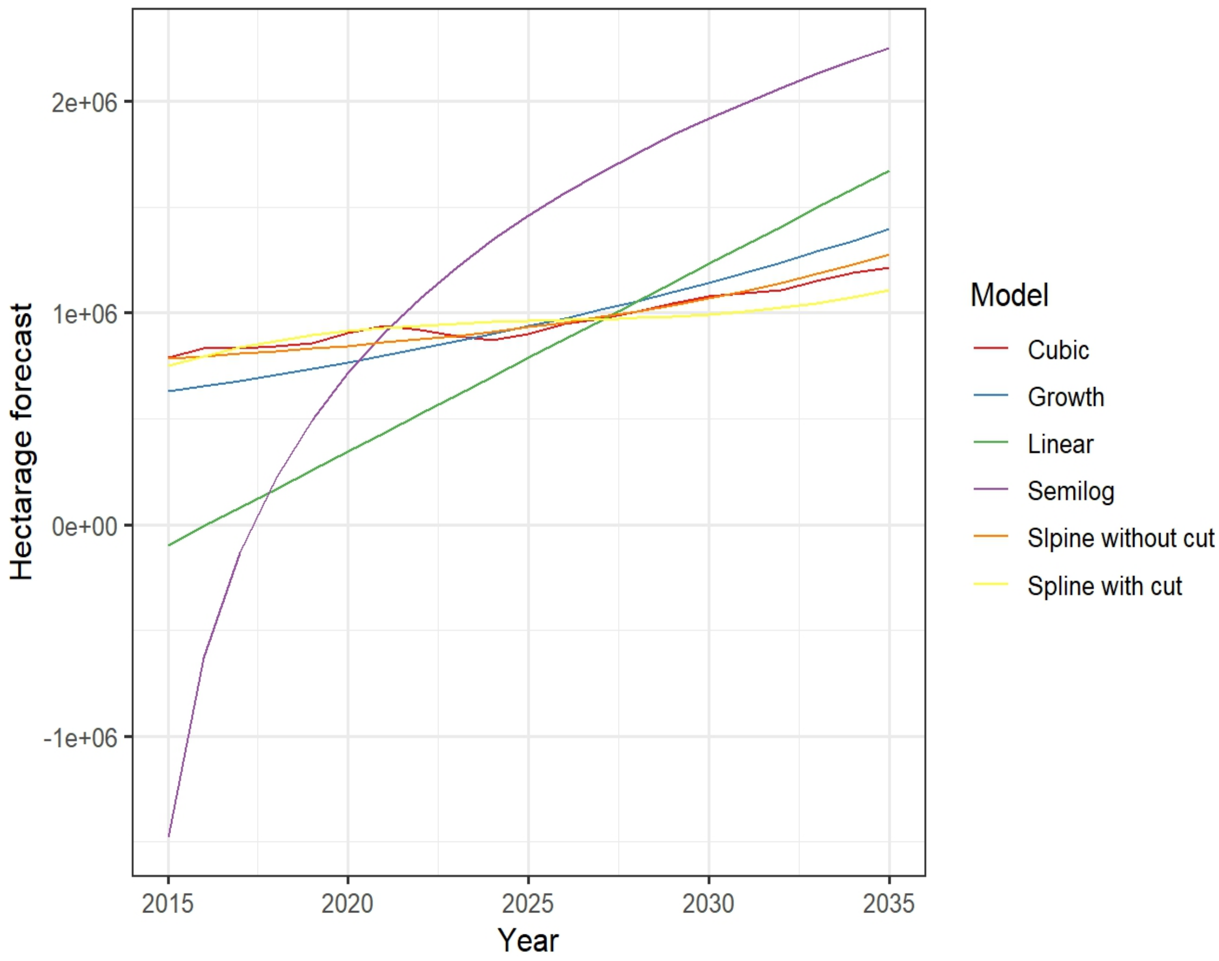


Figure 4.3: Mean forecasts of the models for cassava hectarage

Source: Computer result output, 2019.

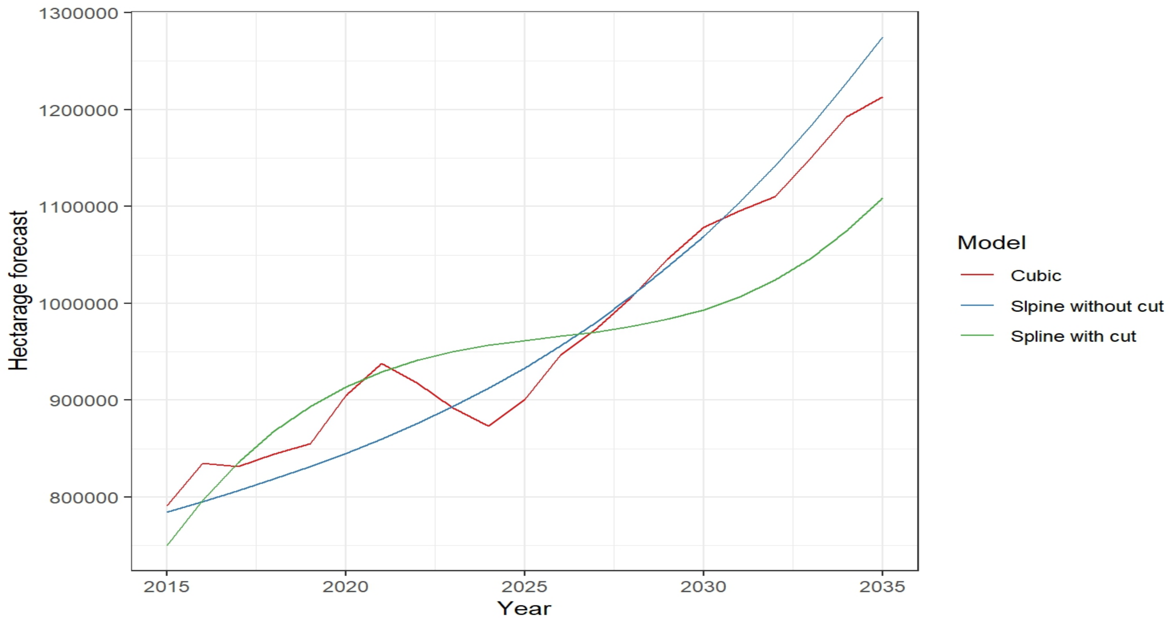


Figure 4.4: Mean forecasts of the grafted polynomial models for cassava hectarage

Source: Computer result output, 2019.

4.4 Estimates of grafted polynomial models for cassava yield (1961-2014).

In this section, the results of all the forecasting models used for the estimation of cassava yield are presented.

4.4.1 Estimates of grafted Polynomial, linear, semi-log and growth models for cassava yield, 1961-2014.

Table 4.7 shows that polynomial model with joint points was significantly different from zero, this means that the quadratic fall and rise in yield observed between 1968 and 1975, 1981 and 1985, 1998 and 2003 was not incidental due to very slow increase in hectarage as indicated in appendix A. In terms of rank, the polynomial model with joint points still was the best, accounting for about 61% of the observed variation in yield of cassava in Nigeria during the estimation period, while the growth model was the poorest accounting for only 2% of the variation. Although, in affirming this fact, more evidence will be provided in subsequent estimations.

Table 4.7: Estimates of the forecasting models for yield of cassava in Nigeria.

Variable	Without Knots	With Knots	Linear	Semilog	Growth
	(1)	(2)	(3)	(4)	(5)
(Intercept)	96.706***	87.248 ***	98.061 ***	91.280 ***	11.495
	(5.049)	(4.953)	(2.982)	(5.150)	(0.030)
bs(niz[, 1], knots = NULL)1	-8.104				
	(1.471)				
bs(niz[, 1], knots = NULL)2	35.340***				
	(9.628)				
bs(niz[, 1], knots = NULL)3	-4.922				
	(7.875)				
bs(niz[, 1], knots = c(21, 31, 41, 50))1		26.474 *			
		(10.965)			
bs(niz[, 1], knots = c(21, 31, 41, 50))2		-5.472			
		(7.194)			
bs(niz[, 1], knots = c(21, 31, 41, 50))3		35.601 ***			
		(7.973)			
bs(niz[, 1], knots = c(21, 31, 41, 50))4		-5.436			
		(7.681)			
bs(niz[, 1], knots = c(21, 31, 41, 50))5		54.135 ***			
		(9.281)			
bs(niz[, 1], knots = c(21, 31, 41, 50))6		-5/652			
		(8.989)			
bs(niz[, 1], knots = c(21, 31, 41, 50))7		-15.539			
		(8.609)			
niz[, 1]			14.806		0.001
			(9.434)		(0.000)
log(niz[, 1])				3.566 *	
				(1.625)	
N	54	54	54	54	54
R2	0.225	0.606	0.045	0.084	0.027
Log Likehood	-571.512	-553.211	-577.147	-576.006	43.009
AIC	1153.025	1124.422	1160.295	1158.012	-80.018

*****1% significant level, **5% level of significance *10% significant level**

Values in parenthesis are computed t-values

Source: Computer result output, 2019.

4.4.2. Grafted polynomial models showing the cut points and tracing path of the data for cassava yield

An examination of figure 4.5 shows that the linear and semi-'log models gave a monotonic increase in the variables during the estimation period. But spline with knots gave a quadratic fall (or rise) at some regions, which were very consistent with the observed data. This shows that the time series data did not linearly relate to trend during the whole period of time and that grafting technique better fit a time series data rather than linear models as attested by Nmadu, *et al.,* (2009) and Bivan, *et al.,* (2014). It was observed in figure 4.6 that the smoothing spline was included in the diagram and it gives the best result, it exactly traces the path of the observed data. From this diagram, cubic spline with joint points and the smoothing spline gave better results during the estimation period. It was observed that the linear and semi-log models gave a monotonic increase of the variables during the estimation period. However, smoothing spline and cubic spline with knots in figure 4.6, gave a quadratic fall (or rise) at some regions or traces the path of the observed data. This shows that the time series data did not linearly relate to trend during the whole period of time and that the grafting technique better fit a time series data rather than linear models as confirmed by Odedukun, *et al.,* (2013).

Table 4.8 shows the goodness of fit properties and turning points of the models under cassava yield, the spline models with and without cuts are adjudged to be the best compared to cubic, linear, semi-log and growth models because of the low level of Mean error (ME), Mean absolute error (MAE), Mean percentage error (MPE), Mean Squared error (MSE), Root mean of the squared error (RSME), Theil's inequality coefficient (U).

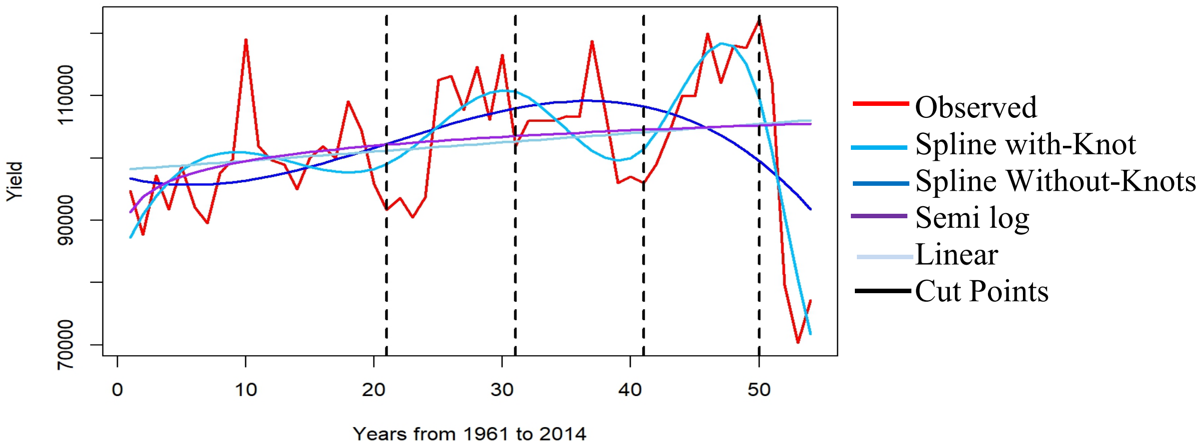


Figure 4.5: Cassava yield 1961 to 2014 showing the cut points

Source: Computer result output, 2019.

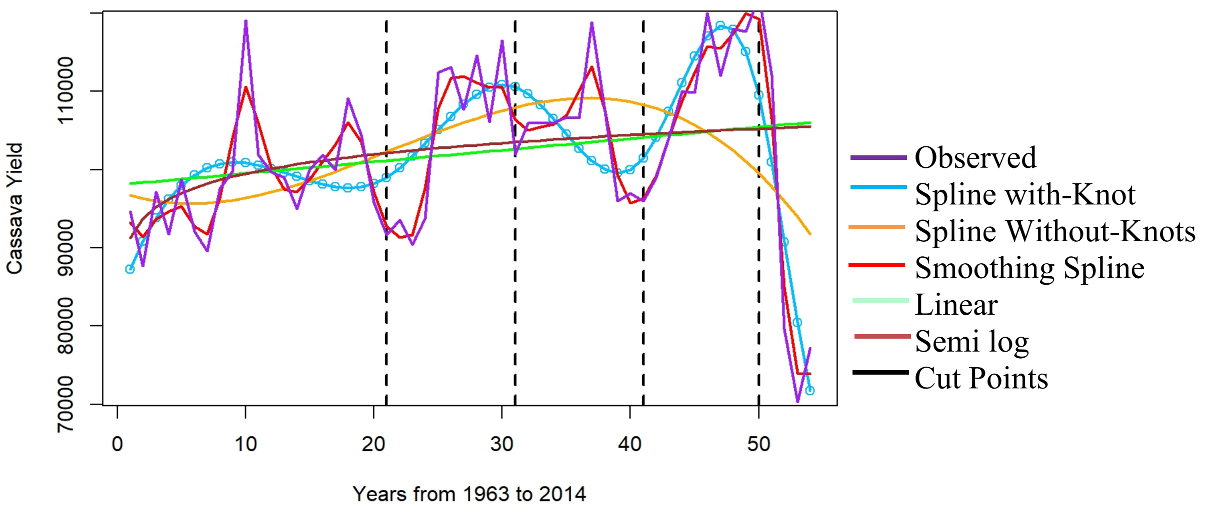


Figure 4.6: Grafted polynomial models showing the tracing path of the observed data.

Source: Computer result output, 2019.

Table 4.8 : Goodness of fit properties and turning points of the models

	Spline-with cuts	Spline-without cuts	Cubic	Linear	Semilog	Growth
ME	-5.400	5.400	-1.500	-5.400	0.000	100.000
MAE	7.5000	5.400	2.600	7.700	7.500	100.000
MPE	-9.400	-4.600	-1.500	-1.200	-1.200	1.000
MAPE	7.500	5.400	2.500	8.000	7.800	1.000
MSE	91.0000	46.0000	9.9000	110.0000	110.0000	110.0000
RMSE	9.600	6.800	3.200	11.000	10.000	100.000
U	1.100	7.800	3.600	1.200	1.200	1.200
Turning points	2.500	2.400	1.500	2.700	2.700	2.700
R-square	0.550	0.180	0.000	0.0270	0.067	0.009
Adjusted R-square	0.550	0.180	0.000	0.0270	0.067	0.009

ME= Mean error, MAE= Mean absolute error, MPE= Mean percentage error, MSE= Mean squared error, RSME= Root mean of the squared error, U = Theil's inequality coefficient

Source: Computer result output, 2019.

4.4.3. Mean forecast of the cassava yield using grafted polynomial models, 2015-2035.

The results of the forecast for cassava yield are presented in figures 4.7 and 4.8. The results shows that both linear, semi-log and growth models are moving in a similar direction with very slow increase in yield, by the direction of their movement, it means that they are not good forecasting models. The cubic model in figure 4.7 and 4.8 exhibit kinked features which means that the model is not capable of giving good estimates. However, a careful examination of figure 4.8, it shows that the spline models with joint points exhibited a kind of quadratic movement but the result of the forecast was not encouraging as it indicated that by the year 2035 the cassava yield in Nigeria is going to be around 98,000 kg/ha. The result is also in conformity with the findings of Dilshad, (2017), that recorded decreasing yield of sugarcane crop in Pakistan which occurred as a result of lack of potential use of resources in sugarcane crop.

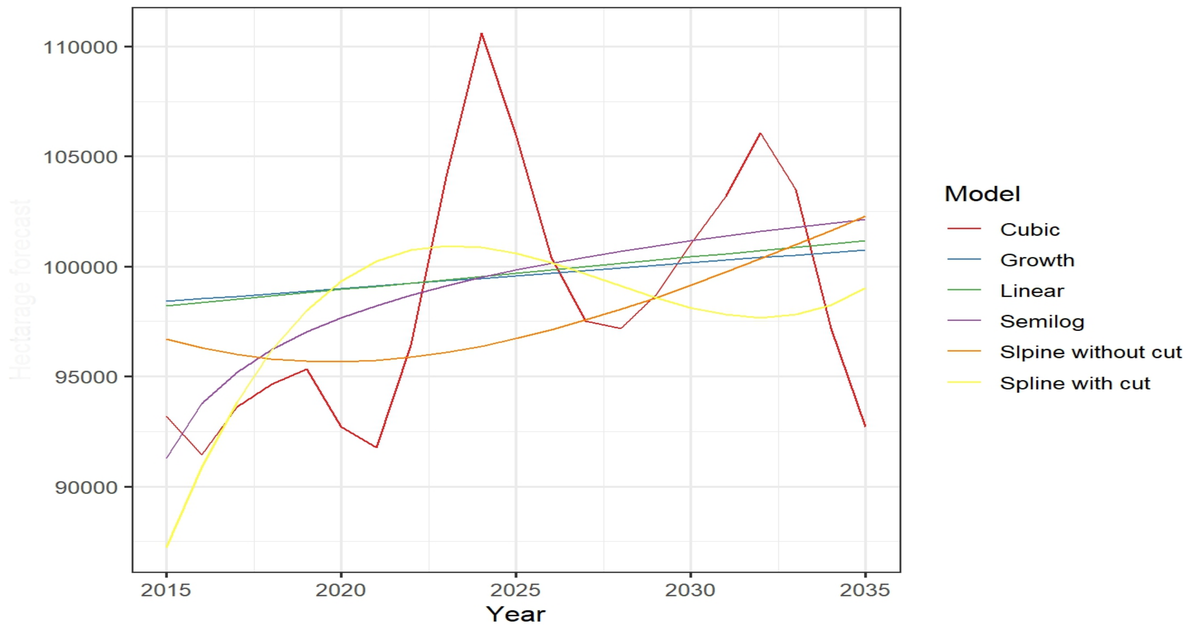


Figure 4.7: mean forecast of the yield models

Source: Computer result output, 2019.

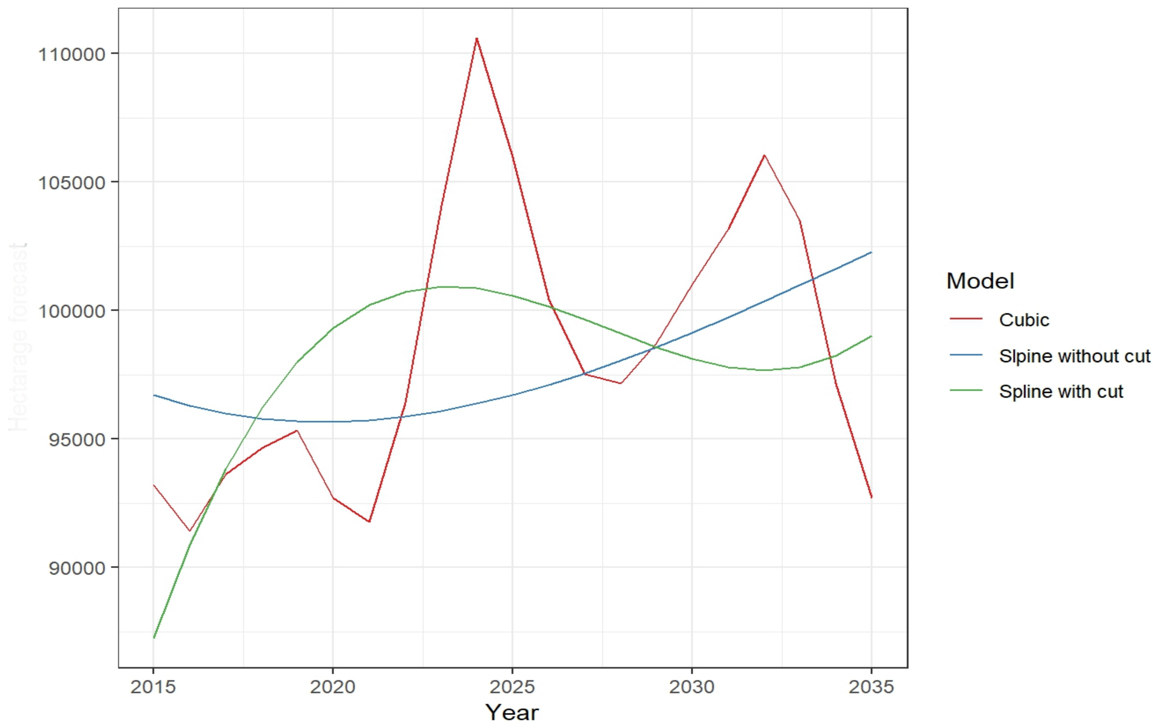


Figure 4.8: mean forecast of the grafted polynomial models for cassava yield

Source: Computer result output, 2019.

4.5 Estimates of forecasting models for cassava output

In this section, the results of all the forecasting models used for the estimation of cassava output are presented.

4.5.1 Estimates of grafted Polynomial models for cassava output

Table 4.9 presents the estimates of the grafted model with and without joint points. The result shows that all the variables are significant at 1% and the quadratic fall and rise from the observed data between 2009 and 2013 did not actually affect cassava output. This suggests that the rise in cassava production actually should have started around 1984. The marginal increase in output after 1984 must have been due to either increase in yield per hectare, better management practices or more efficient input used per unit area. For example, International Institutes for Tropical Agriculture (IITA), Ibadan and National Root Crops Research Institute, Umudike released some cassava varieties in 1983, 1984, 1985, 1996 and 2005 as reported by Eke-okoro and Njoku, (2012). The best fit model was given by grafted model with joint points accounting for 97% of the observed variation during the estimation period while semi-log model gave the lowest fit accounting for 58% variation. Validity checks were conducted on the estimated model as shown in table 4.8.

Table 4.9: Estimates of the polynomial model with four joint points for cassava output in Nigeria.

Variable	Without Knots	With Knots	Linear	Semilog	Growth
	(1)	(2)	(3)	(4)	(5)
(Intercept)	98.223 ***	58.478 **	-12.802	-15.039 **	15.596
	(1.504)	(1.723)	(1.321)	(4.611)	(0.045)
bs(niz[, 1], knots = NULL)1	-11.230 *				
	(4.384)				
bs(niz[, 1], knots = NULL)2	21.433 ***				
	(2.869)				
bs(niz[, 1], knots = NULL)3	40.921 ***				
	(2.346)				
bs(niz[, 1], knots = c(21, 31, 41, 50))1		82.197 *			
		(3.815)			
bs(niz[, 1], knots = c(21, 31, 41, 50))2		-33.999			
		(2.503)			
bs(niz[, 1], knots = c(21, 31, 41, 50))3		17.385 ***			
		(2.774)			
bs(niz[, 1], knots = c(21, 31, 41, 50))4		31.103 ***			
		(2.673)			
bs(niz[, 1], knots = c(21, 31, 41, 50))5		36.101 ***			
		(3.229)			
bs(niz[, 1], knots = c(21, 31, 41, 50))6		41.511 ***			
		(3.128)			
bs(niz[, 1], knots = c(21, 31, 41, 50))7		4837 ***			
		(2.995)			
niz[, 1]			87.375 ***		0.041
			(4.181)		(0.001)
log(niz[, 1])				12.418	
				(1.456)	
N	54	54	54	54	54
R2	0.960	0.972	0.893	0.583	0.939
Log Likelihood	-879.154	-869.225	-906.227	-943.090	21.406
AIC	1768.309	1756.451	1818.454	1892.181	-36.812

***** = 1% significant level, ** = 10% significant level and *= 5% level of significance**

Values in parenthesis are computed t-values

Source: Computer result output, 2019.

4.5.2. Cassava output grafted polynomial models showing the historical path of the models and goodness of fit properties of the models

Figure 4.9, shows the historical path of the data, it was observed that only spline model with joint (knots) points try to trace the historical path of the observed data as shown in figure 4.9 while the spline without joint points, linear and semi log models were at variance with the trend of the observed data. The same thing was applicable to figure 4.10 when smoothing spline was included in the trend of the observed data; it was only spline with joint point that tried to trace the historical path of the observed data meaning that the spline model with joint point was the best model for forecasting.

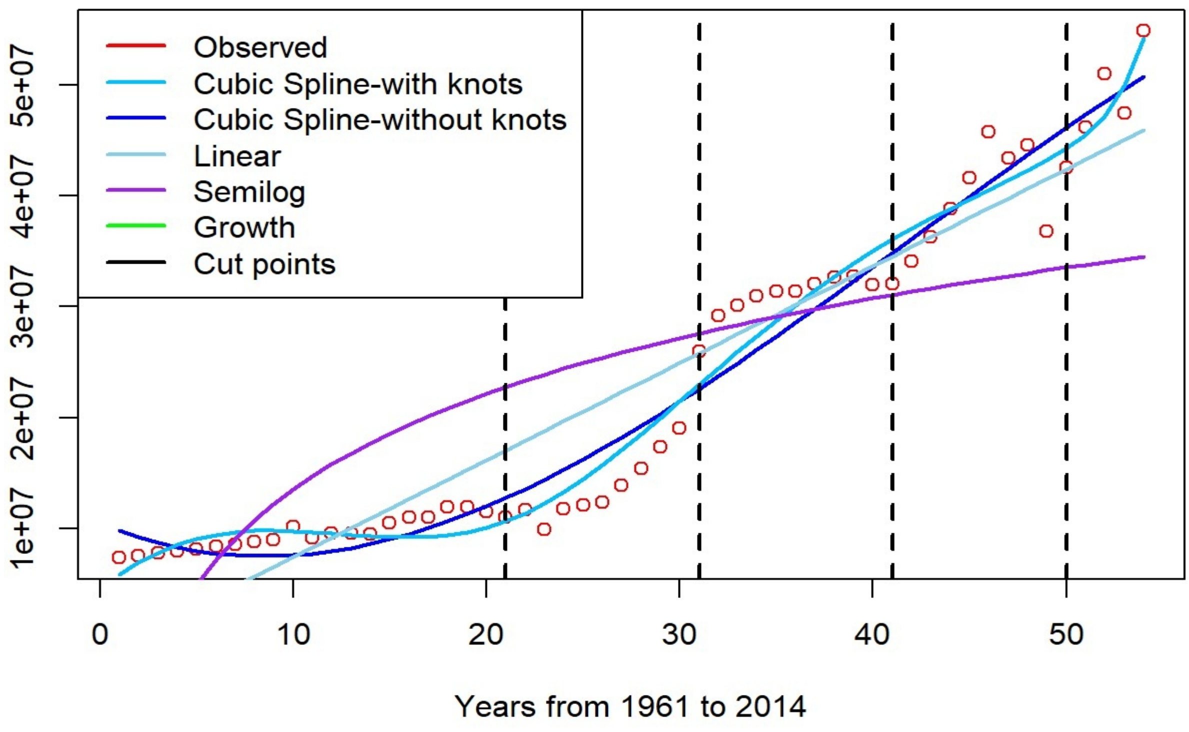


Figure 4.9: Cassava output 1961 to 2014 showing the cut points

Source: Computer result output, 2019.

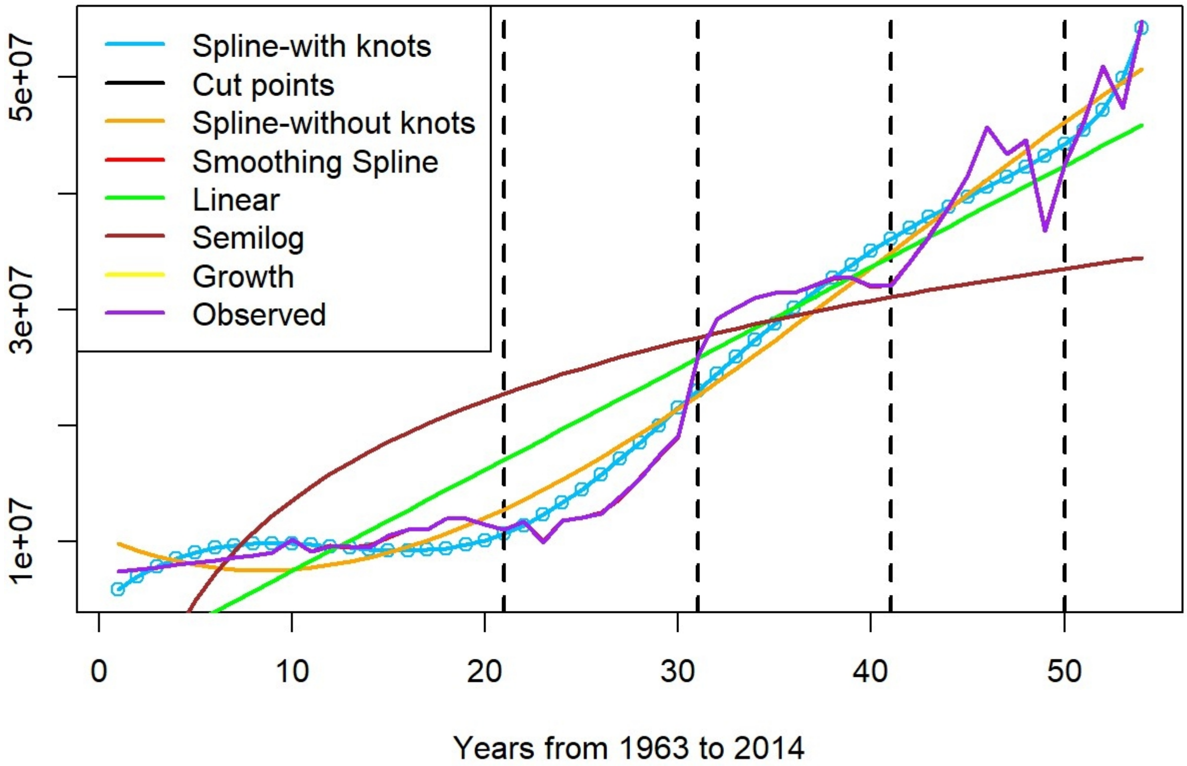


Figure 4.10: Grafted polynomial models showing the tracing path of the observed data. Source: Computer result output, 2019.

Table 4.10 shows the goodness of fit properties and turning points of the models, the spline models with and without cuts are adjudged to be the best compared to cubic, linear, semi-log and growth models because of the low level of Mean error (ME), Mean absolute error (MAE), Mean percentage error (MPE), Mean Squared error (MSE), Root mean of the squared error (RSME), Theil's inequality coefficient (U). The result is in agreement with finding of Saleem, *et tal*., (2014), which showed that grafted polynomial model was appropriate for predicting future estimates of maize area and production in Khyber Pakhtunkhwa due to lowest values of the forecasting errors.

Table 4.10: Goodness of fit properties and turning points of the models

	Spline-with cuts	Spline-without cuts	Cubic	Linear	Semilog	Growth
ME	3.400	0.000	1.600	0.000	9.700	2.307
MAE	23.00000	19.00000	0.25000	38.00000	77.00000	230.00000
MPE	-1.700	-0.970	-0.002	-0.640	-1.300	10.000
MAPE	1.300	9.900	0.180	2.800	5.300	1.000
MSE	81.00000	56.00000	2.2000	2200.0000	8700.000	73000.0000
RMSE	280.0000	240.0000	47.0000	470.0000	930.0000	2700.0000
U	1.200	9.600	19.000	1.900	3.800	1.100
Turning points	1.800	1.400	4.000	1.100	1.100	1.100
R-square	0.970	0.960	0.000	0.890	0.570	0.940
Adjusted R-square	0.970	0.960	0.000	0.890	0.570	0.940

ME= Mean error, MAE= Mean absolute error, MPE= Mean percentage error, MSE= Mean squared error, RSME= Root mean of the squared error, U = Theil's inequality coefficient

Source: Computer result output, 2019.

4.5.3. Mean forecast of the cassava output using grafted polynomial models, 2015-2035.

The results of the forecast for cassava output were presented in figure 4.11 and 4.12. The results show linear, semi-log and growth models moving in a similar direction with very slow increase in output, by the direction of their movement, it means they are not good forecasting models. The cubic model in figure 4.11 and 4.12 exhibit kink features which means the model is not capable of giving good estimates. However, a careful examination of figure 4.12, shows that the spline models with joint points exhibited a kind of quadratic movement but the result of the forecast was not encouraging as it indicated that by the year 2035 the cassava output in Nigeria is going to be about 11,000,000 tonnes which is against the output of about 54,000,000 tonnes obtained in 2014. This result is in agreement with findings of Suleiman and Sarpong, (2012), which employed the Box-Jenkins approach to model milled rice production in Ghana using time series data from 1960 to 2010. Although, a ten years forecast with the model shows an increasing trend in production, the forecast value at 2015 (283.16 thousand metric tons) was not good enough to compare with the 2012 rice production of Nigeria (2700 thousand metric tons), the leading producer of rice in West Africa.

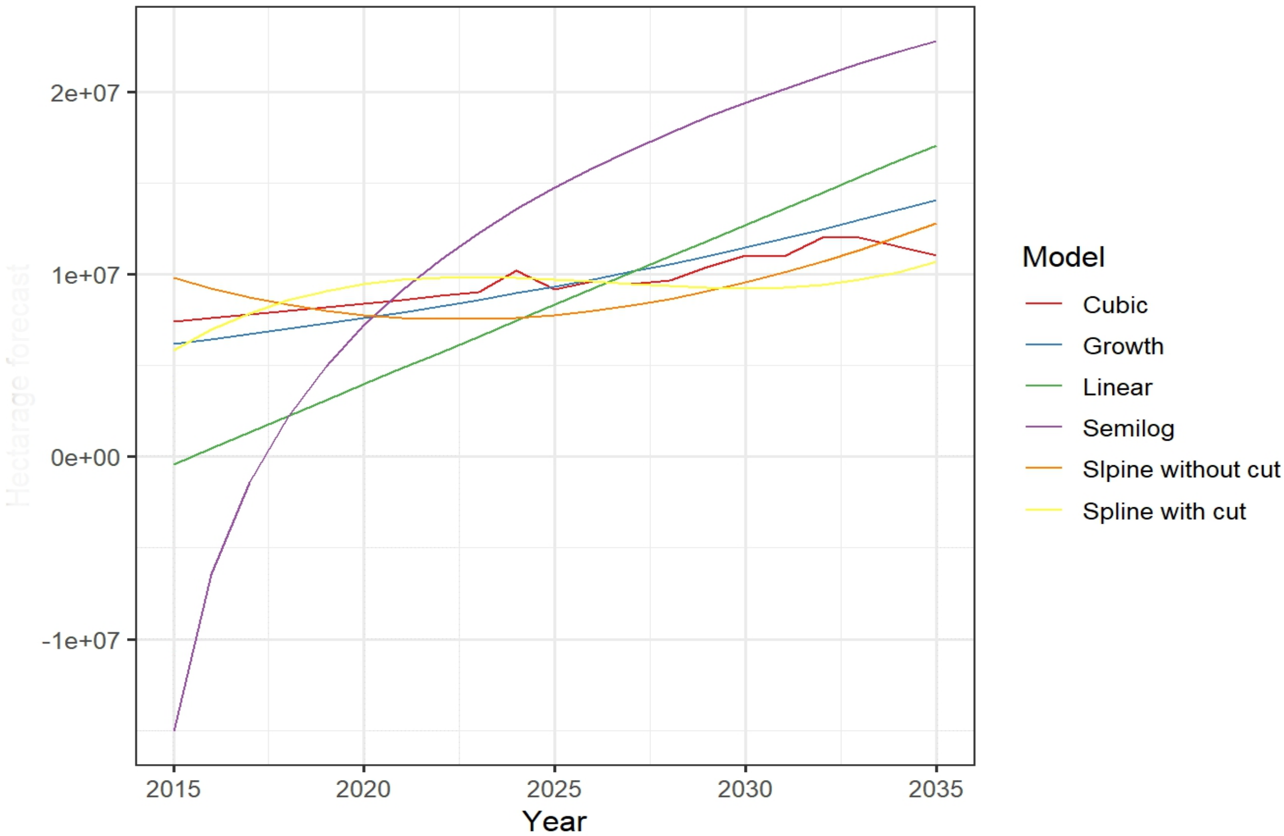


Figure 4.11 : **Mean forecast of the cassava output**

Source: Computer result output, 2019.

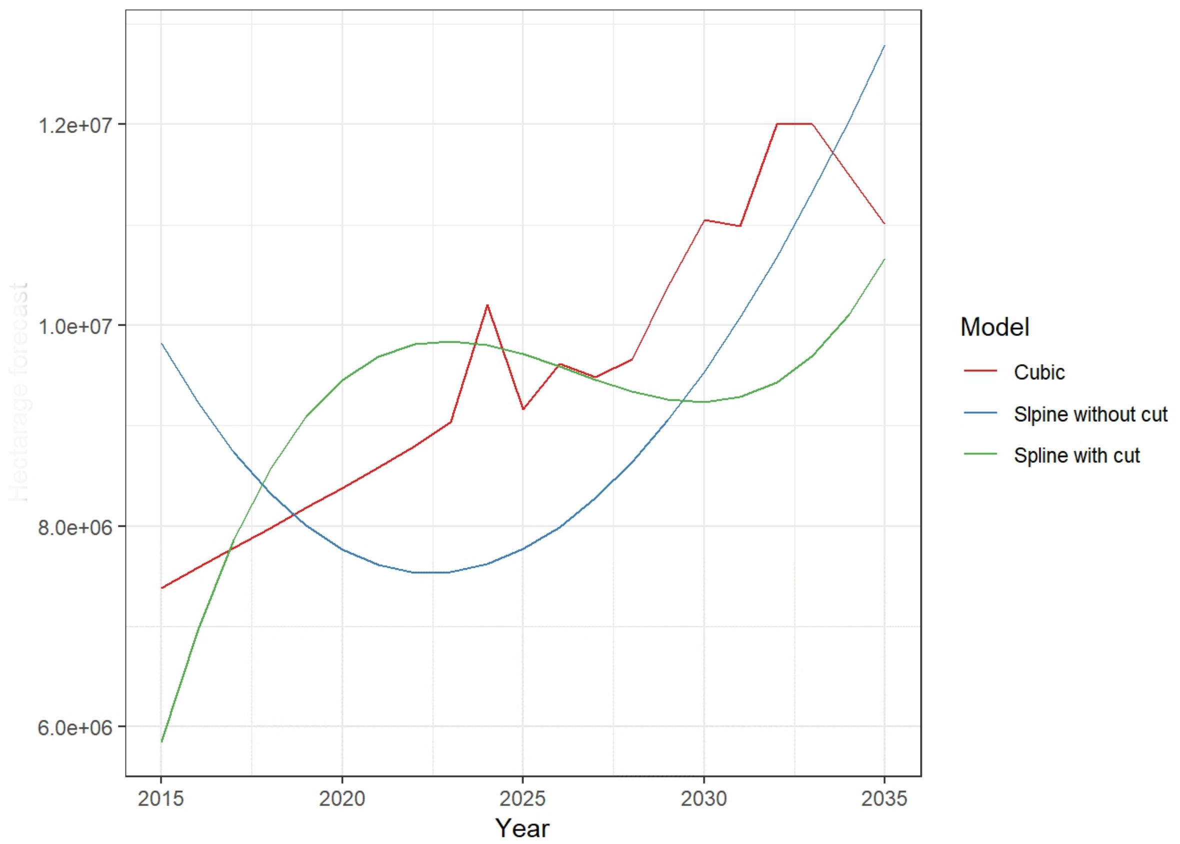


Figure 4.12: Mean forecasts of the grafted polynomial models for cassava output.

Source: Computer result output, 2019.

4.6. Analysis of cassava supply response

In this section, the results of the analysis of cassava supply response using partial adjustment and adaptive expectation models are presented.

4.6.1. Estimated cassava supply response using partial adjustment model

Table 4.11 presents estimates of factors affecting cassava hectarage and factors affecting partial adjustment. The constant of cassava hectarage (14.16) is significant at 10% significant level implying that farmers in Nigeria will allocate 14.2% of their total land to cassava regardless of other observed variables. This is so because cassava is one of the main staple food crop that affect food security among smallholder farmers; therefore land will still be allocated to cassava to carter for food security. The actual price of raw cassava in year t-1 is revealed to be negative and significant. Consistent with this result, the cassava hectarage response is (-1.361e-05) which suggests that a decrease of 1% in price of cassava is liable to decrease a hectarage expansion by about 1.3%. The negative sign and relatively low values of the coefficient obtained from the analysis indicates that cassava producers in making hectarage allocation are influenced more by their expected price than by previous year price.. The estimates for hectarage on cassava actual yield in previous year in table 1 indicates that coefficient of actual yield in previous year is positive and statistically significant at 10% significance level. The coefficient (7.958e-06) suggesting that if rising trend in cassava yield persists it will help farmer's expansion of cassava cultivation in future. This result is in agreement with findings of Phiko, K. (2013).

Similarly, table 4.11 presents the results of the factors affecting partial adjustment coefficients. The results of number of days from January 1 when rain ceased in previous year in table 4.9 was found to be critical in determining the amount of land allocated in the current season, it shows that the coefficient t is positive and statistically significant at 10% level. Based on previous idea when rain ceases early or lately, it will help the farmers to adjust to decisions to either increase or decrease allocation of land to cassava. A negative and significant relationship between cassava yields in year t and hectarage has been found in this study. Recent technology has made it possible for yield to increase within a few hectares of land. On the whole, the variable (yield) was significant at 10%. The coefficient of this variable has been found to be -2.449e-02. This implies that an increase in yield translates into a 0.02% decrease in hectarage allocated to cassava in the next period. This is in conformity with the findings of Muhammad, *et tal*., (2012), that states that the theoretical framework explain that yield may be positive or negative, if comes positive the farmers allocate more to the same crop and if comes negative the farmers reduced the hectarage allocated to that crop.

Table 4.11: Estimates of cassava supply response for partial adjustment model

A.	**Factors affecting cassava hectarage**			
Parameters	estimate	std. error	t value	pr(>| t |)
a_o Constant	1.416e+01	6.000e+01	23.600	0.000002***
a_1 ($P_{t,1}$)	-1.361e-05	7.208e-06	-1.888	0.066530*
a_2 ($Y_{t,1}$)	7.958e-06	1.873e-06	4.249	0.000129***
a_3 ($W_{t,1}$)	2.460e-03	4.724e-03	0.521	0.605441
a_4 (ONt)	6.049e-04	1.343e-03	0.450	0.654967
a_5 (CSt,1)	-5.919e-03	1.917e-03	-3.088	0.003700**
a_6 (PFt,1)	1.365e-04	3.082e-04	0.443	0.660284

B.	**Factors affecting partial adjustment coefficients**			
Parameters	estimate	std. error	t value	pr(>| t |)
b_o (constant)	2.714e+00	1.935e+00	1.402	0.660284
b_1 (Yt)	-2.449e-02	6.292e-03	-3.893	0.000377***
b_2 ($W_{t,1}$)	-5.499e-01	1.343e-00	-0.409	0.684460
b_3 (ONt)	-2.493e-01	7.106e-01	-0.351	0.727614
b_4 ($CS_{t,1}$)	1.957e-01	5.976e-01	3.280	0.002188**
b_5 ($PFt_{,1}$)	-3.511e-01	8.855e-02	-0.396	0.693939

***** = 1% significant level, ** = 10% significant level and *= 5% level of significance**

Source: Computer result output, 2019.

Where,

α, b = structural parameters estimated

$Pt_{,1}$ = price of raw cassava in naira/metric tonne in previous year.

$Yt_{,1}$ = Cassava yield kg/ha in previous year.

ONt = number of days from January 1 when rain commenced in current year.

$CSt_{,1}$ = number of days from January 1 when rain ceased in previous year.

$PF_{t,1}$ = price of fertiliser in naira/metric tonne in previous year

$W_{t,1}$ = wage rate in naira/man-day in previous year.

4.6.2 Estimated cassava supply response for adaptive expectation

The adaptive expectation hypothesis emphases that the harvest time prices are not observed during the time of planting. Thus, the farmers make expectation about output prices based on their knowledge of past and present prices as well as other relevant observable variable. The results of the adaptive expectation hypothesis in table 4.12 show that price of raw cassava in previous year significantly and positively increased cassava supply at 1% significance level. This means that, 1% increase in price would result in 1.1% increase in cassava supply. As expected the annual rainfall also positively and significantly increased cassava supply. A 1% increase in amount of rainfall in a year induces cassava supply to increase by 1.3% this in line with the findings of Imeh, (2014).

Duration of rain in a year was significant at 5% significance level. But contrary to expectation, duration of rain in a year was found to be negatively related to the cassava supply. A decrease in duration of rain will result in 0.017% decrease in cassava supply. This indicates that, even though cassava is resistant to drought it requires adequate amount of water for better yield. Similarly, price of fertilizer was found to be negatively related to the cassava supply, which means that an increase in the price of fertilizer will decrease the supply of cassava. This finding is in agreement with Ifeanyi, *et tal.* (2017), reported that price and shortage of fertilizer were some of the cassava production challenges in Nigeria. The researchers affirmed that about 60.10% of cassava famers were complaining of non-availability and high price of the fertilizer in cassava production. This clearly indicates that farmers' willingness to supply cassava will depend on the price and availability of fertilizer. Temperature also plays a vital role in cassava supply. It was found that temperature was positively and significantly related to cassava supply at 5% significance level which means that temperature will lead to high supply of cassava.

Table 4.12: Estimates of cassava supply response for adaptive expectation model

A.		**Factor affecting cassava hectarage**		
Parameters	Estimate	Std. error	t value	pr(>| t |)
a_o (Constant)	6.944e+05	4.330e+06	0.160	0.87350
a_1 (P_{t-1})	1.081e+02	2.012+0	5.371	5.22e-06***
a_2 (R_{t-1})	1.296e+03	4.869e+02	2.661	0.01167*
a_3 (DU_{t-1})	-1.708e+03	9.621e+02	-1.775	0.08454*
a_4 (RD_{t-1})	2.700e+03	4.113e+03	0.656	0.51586
a_5 (Ti_{t-1})	-2.122e+01	5,544e+01	-0.383	0.70415
a_6 (TM_{t-1})	-1.993e+04	1.287e+05	-0.155	0.87785
a_7 (HM_{t-1})	-2.851e+03	1.360e+04	-0.210	0.83516
a_8 (PF_{t-1})	-4.809e+02	1.718e+02	-2.799	0.00828**

B.		**Factor affecting adaptive expectation coefficients**		
Parameters	Estimate	Std. error	t value	pr(>| t |)
b_o (constant)	-1.749e+01	7.461e+00	-2.344	0.02489*
b_1 (Rt)	-1.516e-03	7.590e-04	1.998	0.05356*
b_2 (DUt)	3.224e-03	2.437e-03	1.323	0.19442
b_3 (RDt)	-9.018e-03	4.635e-03	-1.945	0.05980*
b_4 (Tit)	-9.100e-03	8.248e-05	-1.103	0.27740
b_5 (TMt)	4.536e-01	2.257e-01	2.010	0.05221*
b_6 (HMt)	9.406e-03	2,292e-02	0.410	0.68406
b_7 (PFt)	-3.292e-05	2.935e-05	-1.121	0.26971

***** = 1% significant level, ** = 10% significant level and *= 5% level of significance**

Source: Computer result output, 2019.

Where:

$Pt_{,1}$ = price of raw cassava in naira/metric tonne in previous year.

$Rt_{,1}$ = annual rainfall in mm in previous year t

$RDt_{,1}$ = number of rain days in previous year t

$DUt_{,1}$ = duration of rain in previous year t

Tit = minimum temperature in current year.

TMt = maximum temperature in current year.

$PFt_{,1}$ = price of fertiliser NGN/metric tonne in previous year.

HMt = relative humidity in current year.

α's, b's = structural parameters estimated

4.6.3. Comparative analysis of partial adjustment and adaptive expectation models

The results show which of the models among the partial adjustment model and adaptive expectation model better trace the historical path of the data. Figures 4.13 and 4.14, shows the historical trace path of the data. It was observed that the partial adjustment model more appropriately modeled the historical data than the adaptive expectation. Moreover, this fact is further confirmed by the validity test in table 4.13. For example, while the mean percentage error (MPE) was about 1.2% and mean absolute percentage error (MAPE) was 7.9% with the partial adjustment hypothesis, the adaptive expectation hypothesis has 3.4% MPE and 14.9% MAPE. Furthermore, figures 4.13 and 4.14 indicated that supply has increasing functions and the shifter variable acted both directly and indirectly through the adjustment parameters, to alter cassava supply. In addition, this assertion is a confirmation of the fact that the hectarage decision from year to year is perfectly under the control of the farmer and this makes hectarage a better proxy for supply than output which is a function of weather, management and other risk situation during the growing season. These risk factors in most cases are unique each year making it more difficult to handle, The observation form both figures show that the trends have been on steady increase from 1963 indicating that rather than the error of forecast and level of ignorance to decrease, it was rather increasing. This trend is hardly surprising because of the frequency of changes in major policy direction of the economy.

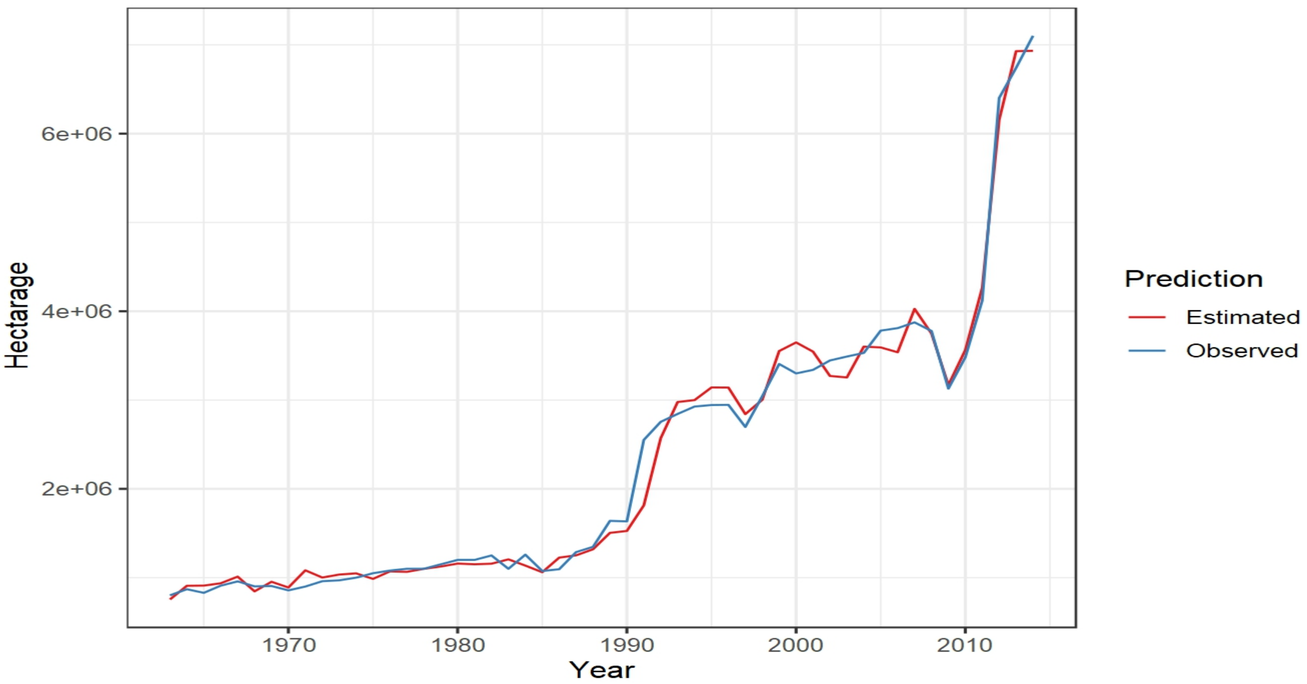


Figure 4.13: Comparison between the observed and estimated hectarage of cassava using partial adjustment model

Source: Computer result output, 2019.

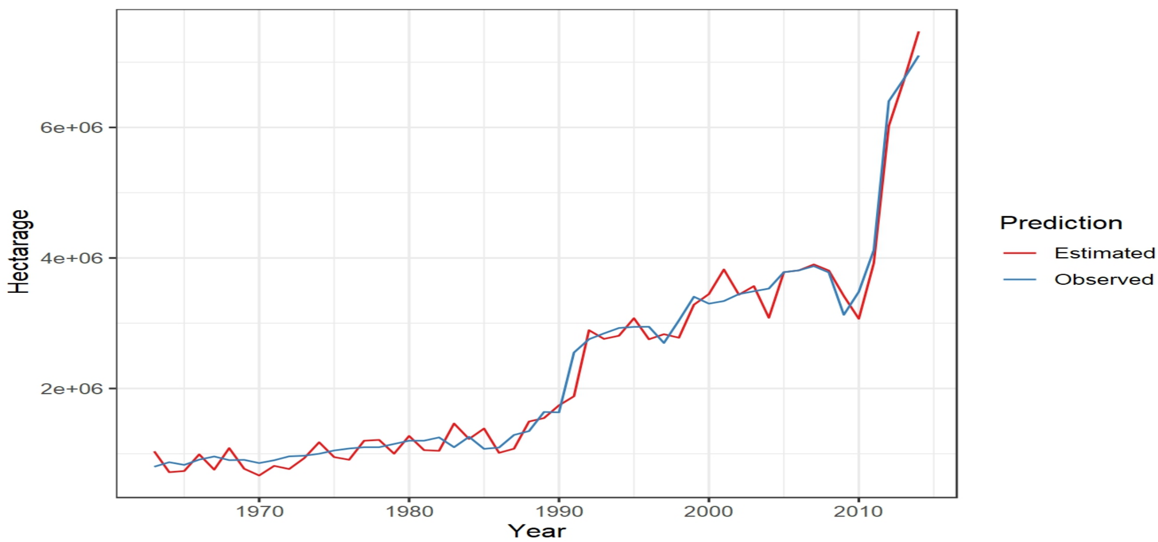


Figure 4.14: Comparison between the observed and estimated hectarage of cassava from adaptive expectation model

Source: Computer result output, 2019.

Table 4.13: Goodness of fit of the partial adjustment and adaptive expectation models

Variables	ME	RMSE	MAE	MPE	MAPE	MASE
Partial Adjustment	58926.67	352187.2	284499.7	1.237024	7.931683	0.99594
Adaptive expectation	163231.1	494632.8	317857.8	3.360372	14.89352	1.04334

ME= Mean error, RSME= Root mean of the squared error, MAE= Mean absolute error, MPE= Mean percentage error, MSE= Mean squared error, MAPE= mean absolute percentage error

Source: Computer result output, 2019.

4.6.4. The estimated coefficients of partial adjustment and adaptive expectation

The estimated coefficients of partial adjustment and adaptive expectation are presented in appendix D. The first and second hypothesis of this study states that there was no variation between the trend and the coefficient of adaptive expectation and partial adjustment of cassava supply response in Nigeria. That is, the coefficients does not vary from year to year but are fixed at a particular level. From figures 4.15 and 4.16, it was clearly shown that there were variations between the trend and the coefficients of adaptive expectation and partial adjustment, therefore, the two hypotheses are rejected. It was observed that the estimated coefficients from 1963 to 2014 of partial adjustment are higher than that of adaptive expectation. Appendix D shows the mean coefficient of partial adjustment hypothesis as 4.69E-07 and adaptive expectation hypothesis is -0.256186542. The magnitudes of the coefficients of both partial adjustment and adaptive expectation are very low which indicates that farmers' adjustment rate was very low. This finding is in agreement with finding of conteh *et al,.* (2014), who found the famers' rate of adjustment to be very low too.

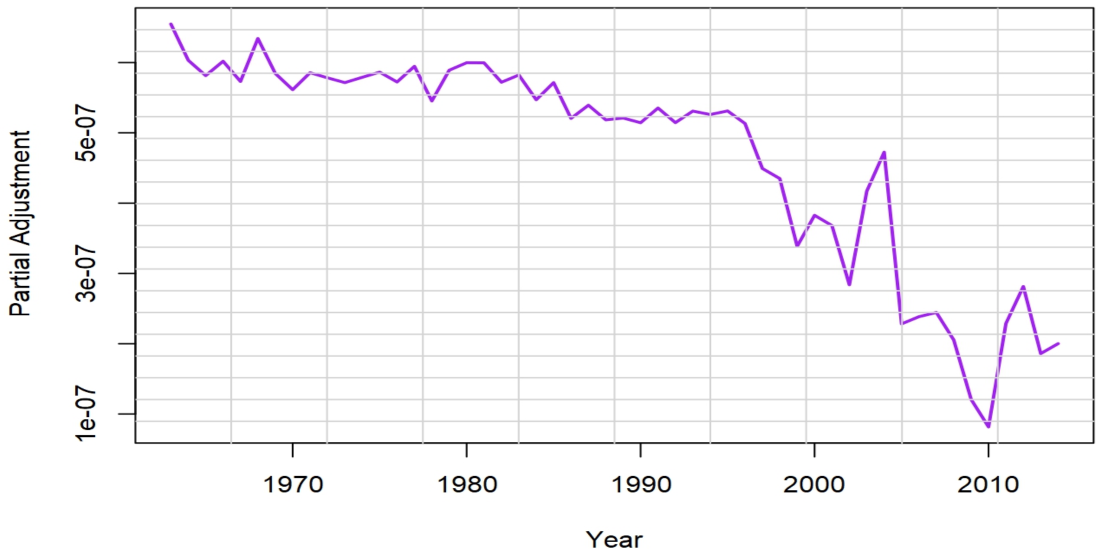


Figure 4.15. Estimated partial adjustment coefficients

Source: Computer result output, 2019.

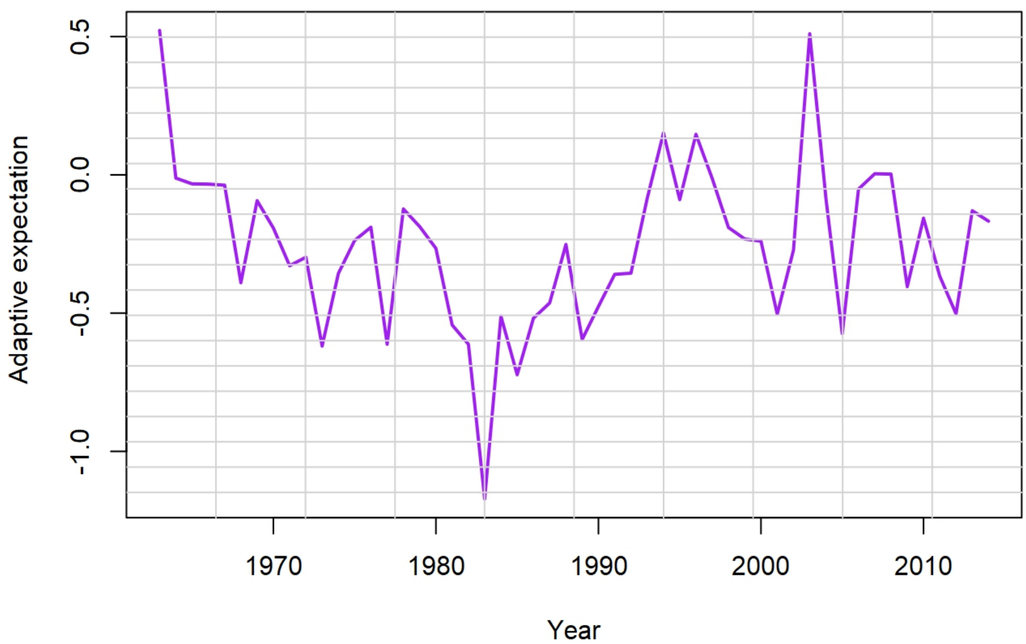


Figure 4.16 Estimated adaptive expectation coefficients

Source: Computer result output, 2019.

4.7. Forecast of cassava supply using partial adjustment and adaptive expectation Models.

The results of the forecast for cassava supply in Nigeria using partial adjustment and adaptive expectation models to year 2064 are presented in figures 4.17 and 4.18. The result of partial adjustment model shows that the mean forecast lies between the 95% lower and upper bound of confidence level also the mean forecast lies between 80% lower and upper bound of confidence level. By year 2064, the cassava area would be 0.6e+08 hectares The results of the mean forecast for cassava hectarage in Nigeria using adaptive expectation model shows that by the year 2064 cassava area would be 0.75e+07. The mean also lie between 80% and 95% lower and upper bound confidence level. This result is related to the findings of Badmus and Ariyo (2011). Their result shows maize production forecast for the year 2020 to be about 9,952.72 tons with upper and lower limits 6,479.8 and 13,425.64 thousand tons respectively. The model also showed that the maize area would be 9,229.74 thousand hectares with lower and upper limit of 7,087.67 and 11,371.81 thousand hectares respectively by 2020. The result indicates that there was a high forecast of cassava hectares to be cultivated by year 2064 using partial adjustment model than adaptive expectation model. In this case, partial adjustment model is more suitable in forecasting cassava hectarage in Nigeria.

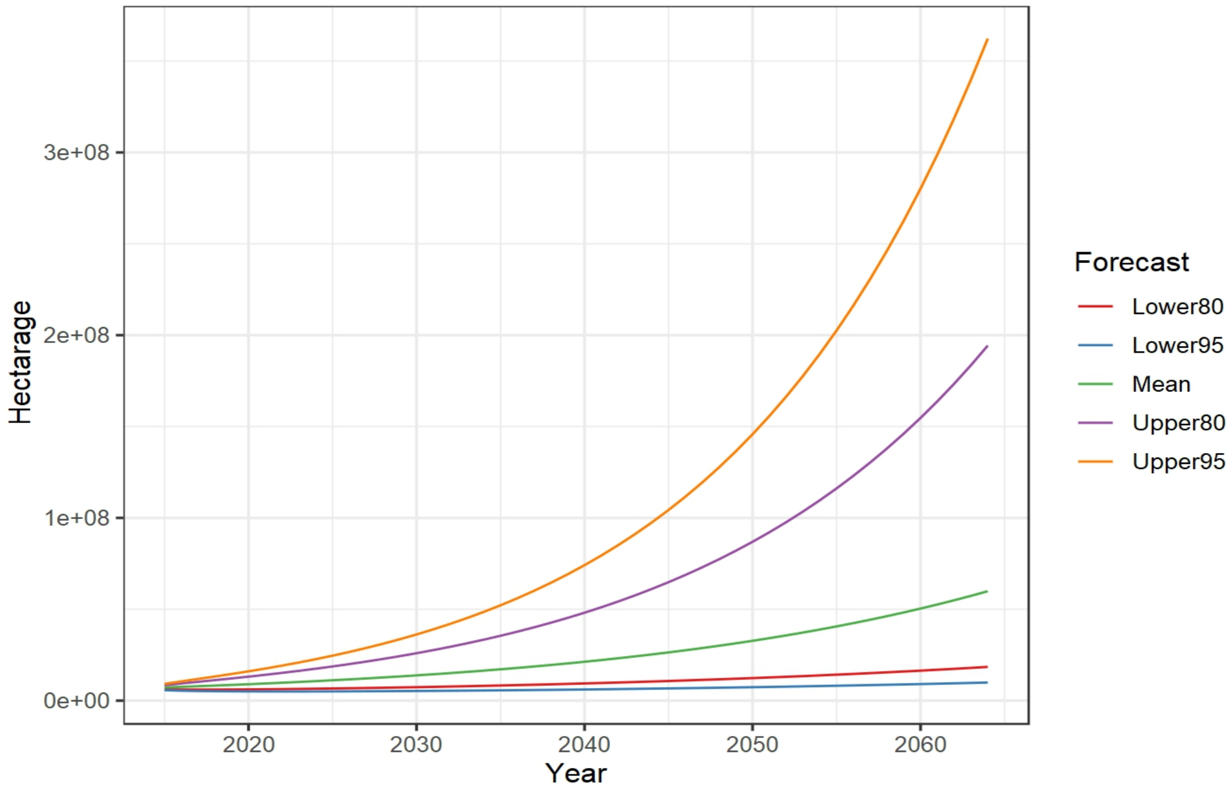


Figure 4.17: Forecast of cassava using the partial adjustment model to 2064
Source: Computer result output, 2019.

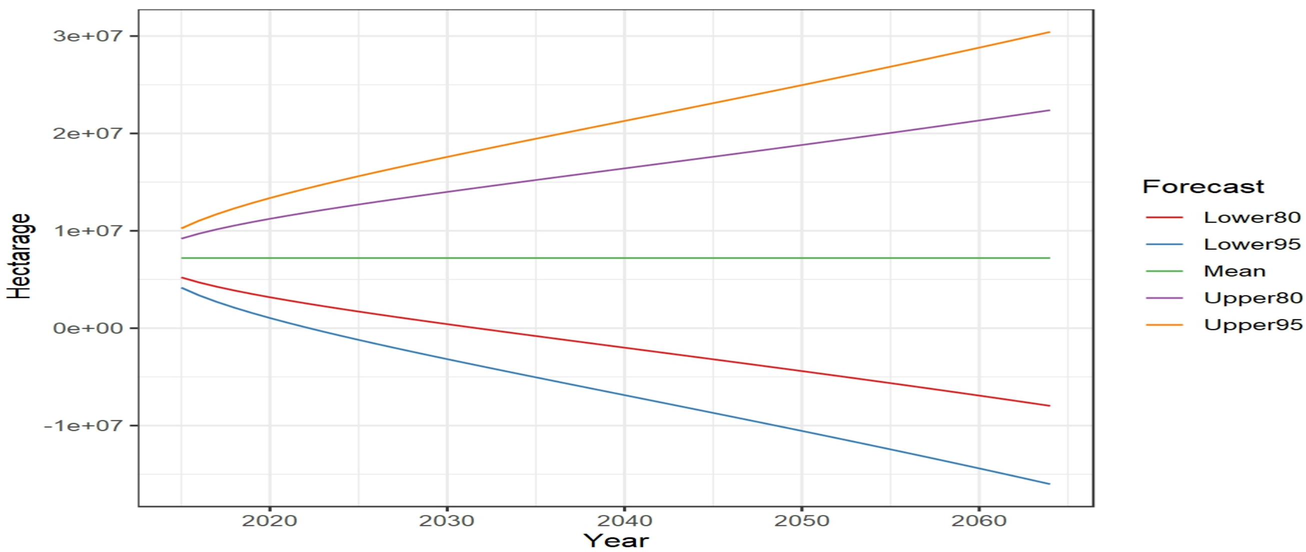


Figure 4.18: Forecast of cassava using the adaptive expectation model to 2064
Source: Computer result output, 2019.

4.8. Price elasticity of cassava supply

In this section, the results of short run and long run price elasticity of cassava supply for partial adjustment and adaptive expectation are presented.

4.8.1. Estimates of price elasticities of cassava supply

The estimated elasticities of supply are presented in appendix E. The results conform generally with expectation that long run elasticity is larger than short run except for some years which turn out to be otherwise. This is because, no matter the changes that occur in prices and other factors, farmers are unable to change their production plan in the short run, that is, period of gestation of the cop or within the growing season. However, on the long run, because better or perhaps worse information, the farmer is able to alter his plan. The distributions of the various elasticities were generally significantly differently from zero at 5% level that is, the elasticities were inelastic hence the second hypothesis was rejected. These low values of elasticities might be due to the subsistence nature of Nigerian farmers. They might have some cash obligations to settle (especially around the harvest time), as such they are forced to sell no matter the price. This means that at high prices they sell less quantity while at lower prices, they sell more quantity, and as soon as the cash needed is obtained, they stop selling. This phenomenon has given rise to wide spread of hoarding of agricultural produce by the rich since supply at harvest always far outweigh demand, forcing the price downward. From appendix E, the result shows that on average, cassava supply has adjusted to changes in prices from 1963 to 2014 by -8.418E-15 (short run) and -2.74E-08 (long run) for the partial adjustment model and by -3.97E-02 (short run) and 0.217804 (long run) for the adaptive expectation model. Therefore, cassava supply is generally relatively inelastic. It appears that farmers did not have advantage of time to change their hectarage since both short run and long run are fairly inelastic. This result is in agreement with the findings of Muchapondwa, (2009); Sadiq *et al.,* (2012) and Ime, (2014) who in their separate researches found both short run and long run elasticities to be inelastic.

4.9 Cassava economy in Nigeria

Effort was made to determine the type of impact the various policies changes have had on cassava production in Nigeria. For easy understanding of this research work it is very important to highlight some economic values of the analysis. The mean trend values of hectarage, yield and output of cassava covering the period 1961–2014 are classified as the pre-SAP, SAP (Structural Adjustment Programme), post-SAP and Agricultural Transformation Agenda (ATA) periods. It was observed that there was a drastic decline in cassava yield during structural adjustment programme and agricultural transformation Agenda but the same periods under study, cassava hectarage and output sow remarkable improvement. The result of the overall mean of the various policies indicated a decline in yield of cassava in Nigeria. This means that the farmers were not adopting the modern technologies that were available for them

Nigeria is witnessing rapid population growth and demand of cassava always on the high side because most of the cassava produce are consumed locally. The results of the forecast (2015-2035) presented in figures 4.4, 4.8 and 4.12 revealed that cassava hectarage, yield and output will be 11,200,000 hectares, 98,000 kg/ha and 11,000,000 tonnes respectively. This shows that too much hectares will be allocated to cassava by the year 2035, in order to minimize the use of land, effort should be geared towards increasing yield instead of increasing hectares, this can be done by adoption of technology and research institutions should produce cassava seedling that gives high yield per hectare. This research also observed that cassava farmers are less responsive to policy incentives both in the short run and long run. The partial adjustment model shows that the short run and long run coefficients are -8.41e-15 and -2.74-

08 respectively, also the adaptive expectation model shows that the coefficients of short run and long run would be -3.9e-02 and 0.217803916 respectively. This shows that the elasticity of supply is inelastic.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The findings of the research revealed that the trend of cassava hectarage and output from 1961 to 2014 shows an increase in the growth rate of cassava in Nigeria during Pre-SAP, SAP, Post SAP and ATA periods but declining yield the same period under study.

The findings of the research also revealed that, the most suitable and appropriate models in forecasting cassava production in Nigeria were the spline model with knots and spline model without knots. The results of the forecast for cassava hectarage, yield and production by the year 2035 shows increasing trend but it was below expectation.

The general trend of cassava farmers' reaction to changes in incentives and policies has been very low as exemplified by the coefficients of adjustment and price elasticity of supply. Hence, the time needed to complete adjustment is generally very long, probably cassava farmers either under or overestimate the effect of changes in production.

The two hypotheses proposed using adaptive expectation coefficients, partial adjustment coefficients, short run and long run elasticities were rejected because farmers' reaction to changes in prices and other economic incentives are not fixed but dynamic and concluded that cassava production in the past has been done in dynamic environment not isolated.

The researcher simulated four joint points' grafted polynomial model using time series data for forecasting cassava production. Nerlove supply response model was also modified with the inclusion of temperature and relative humidity, the result was found to be positive and statistically significant in cassava supply in Nigeria. These formed the basis for bridging the knowledge gab.

5.2 Recommendations

Based on the findings of this study, the following recommendations were made.

1. The results of this study found that there was the need to establish the short term and long term cassava needs base on present population rate of growth and employ the models estimated to establish, hectarage, yield and output that will provide this need. The levels of technical and allocative efficiency that will achieve this need should be determined by the research authorities.
2. The estimated elasticities of cassava supply are useful guide in studying the responsiveness of the farmers especially with regards to price and can be used in studies where such an estimate is required.
3. Effort should be made by the government and private sectors like non-governmental organisation to provide the needed input to the farmers at affordable rates, especially seedling and chemicals. Also farm input should be subsidized by the government in order to reduce cost of production and hence encourage more people to go into commercial farming of cassava in the country.
4. Due to paucity of data in carrying out economic analysis there is the need to have a comprehensive data bank that supplies data on demand. It might be necessary to convene a conference on data collection, processing and utilization to bring together agencies that are concerned with collection and agencies that use them.
5. The marketing policies to be adopted should not only enhance farmers' income but should also facilitate food security. Government should reintroduce minimum and maximum pricing policy with enough resources to guard it.
6. Technology played a vital role in agricultural development especially in cassava production. Therefore, there is the need for farmers to be trained on modern technology of farming.

5.3 Limitations and suggestions for further study

This study has not been considered all the aspects of forecasting and supply responses that limit the scope of the study due to time and data constraint. Thus, the discussion of limitations of the findings have resulted the scope for further research. One of major problems of this research is the inadequate data and where the data is available there was problem of accessibility. It might be necessary to convene a conference on data collection, processing and utilization to bring together agencies that are concerned with collection and agencies that use them. The cost of data bundle used in accessing internet for the research and analysis especially where latest r-software package was employed is very high, there is the need to subsidies cost of data bundle for researchers.

Time series data usually gives spurious result when not stationary and effort to make it stationary might lead to loss of some vital information, in view of this there is the need for research to address this problem. The universal grafting of time series data using grafted polynomial model stopped at three segments or joint points, this research was able to simulate four joint points of grafted polynomial models but due to long process of derivation, the researcher could not proceed to the fifth or higher joint points, there is the need for further study to simulate model with five or ten joint points. The annual mean temperature incorporated in Nerlove model though shows significant results but it will be better if other researchers could use daily or monthly temperature, which may give better results.

In order to complement this study with studies to confirm the assumptions made in this study so as to increase the knowledge base of decision and policy makers and hence provide a more variable tool that will help to transform agriculture in Nigeria. Therefore, the following assumptions should be tested: whether farmers respond to price incentives and whether farmers actually form hectarage decision and price expectation based on future prices and past prices.

References

Abu, G. A., Ater, P. I. & Tor, I. E. (2015). Long run co-integration modelling for rianfall, yield and prices of Cereals and Legume in Nigeria. *Asian Journal of Agricultural Extension, Economics and Sociology, 4(1), 86-100.*

Abdulahi, A. (2003). Employment Creation and Opportunities in the Agro-Allied Sub-Sector; The Case of Cassava Production. *The Bullion Publication of CBN, 27(4), 1-10*

Agboola, F. W., & Evans, N. (2012). Modelling rice and cotton acreage response in the Murray Darling Basin in Australia. *Agricultural Systems elsevier, 107, 74-82.*

Aizenman, J. & Jinjarak, Y. (2009). Current account patterns and national real estate markets. *Journal of Urban Economics, 66(2), 75-89.*

Akanni, K. A. & Okeowo, T. A. (2011). Analysis of aggregate output supply response of selected food grains in Nigeria. *Journal of Stored Products and Postharvest Research, 2(14), 266–278.*

Akinpelu, A. O., Amamgbo, L. E., Olojede, A. O., & Oyekale, A. S. (2011). "Health implications of cassava production and consumption", *Journal of Agriculture and Social Research, 11(1), 38-54.*

Akintunde, O. K; Okoruwa, V. O., & Adeoti, A. I. (2013). The effect of agroclimatic factors on cash crops production in Nigeria. *Journal of Central European Agriculture, 14(3), 52-74.*

Akoroda, M. O., Gebremeshel, I., & Oyinlola, A. E. (1989). Impart of IITA cassava varieties in Oyo State, Nigeria, 1976- 1985. *Journal of Tropical Agriculture, 66(2), 113-120.*

Anyanwuocha, R. A. (2013). *Fundamentals of Economics for SSCE, NBCE, UTME.* (3rd ed.). Onitsha, Nigeria. Africana First Publishers.

Askari, H., & Cummings, J. (1977). Estimating agricultural supply response in the Nerlove Model. *International Economic Review, 5(19), 45-60.*

Askari, H., & Cummings, J. (1977). Estimating agricultural supply response with the Nerlove model: a survey. *International Economic Review, 18(2), 257-292.*

Asante-Pok, A. (2013). Analysis of incentives and disincentives for cassava in Nigeria. Monitoring African Food and Agricultural Policies project (MA-FAP), FAO, Rome, Italy. Retrieved from http://www.fao.org/3/a-at582e.pdf.

Coyle, B. T., Wei, R., & Rude, J. (2008). Dynamic econometric models of Manitoba crop production and hypothetical production impacts for CAIS. CATPRN *Working Paper,* Department of Agribusiness and Agricultural Economics, University of Manitoba, Manitoba. Retrieved DOI:10.220044/ag.econ.46630.

Badmus, A. & Ariyo, M. (2011). Forecast of area and production of maize in Nigeria. *Contemporary Issues journal, 2(10), 32-37.*

Baulch, R.J. (1995). Spatial price equilibrium and food market integration, a Ph.D Thesis of the Stanford University.

Beddow, J. M., Philip, G. P., Jawoo, K. & Wood, S. (2010). Changing the landscape of global agriculture. In Julian M. A., Bruce A. Babcock and Pardey P.G. (Eds.), *The Shifting Patterns of Agricultural Production and Productivity Worldwide* (pp.7-35). Iowa: The Midwest Agribusiness Trade Research and Information Center, Iowa State University.

Bingxin, Y., Fengwei, L. & Liangzhi, Y. (2013). Dynamic agricultural supply response under economic transformation: A Case Study of Henan, China. *American Journal of Agricultural Economics, 94(2), 370- 376.*

Bivan, G. M., Akhilomen, A., Augustine, J. & Rahman, S. A, (2013). Comprehensive analysis of linear grafted polynomial function in forecasting Sorghum production in Middle-east. *Journal of Scientific Research, 15(10), 1411-1414.*

Bridges, D., & Tenkorang, F. (2009). *Agricultural commodities acreage value, elasticity over time-implications for the 2008 Farm bill.* Paper presented at the American Society of Business and Behavioral Sciences Annual Conference, Las Vegas, NV.

CBN. (2012). Central Bank of Nigeria Statistical Bulletin, November 1st, 2012.

CBN. (2004). Statistical Bulletin. Central Bank of Nigeria.

CIAT. (1993). *Centre International de Agricultural Tropicale*. *Cassava*: The latest facts about an ancient crop. CIAT, Cali Colombia. pp. 1-10.

Conteh, M. H., Xiangbin, Y., & Alfred, V.G. (2014). Using the Nerlovian adjustment model to assess the response of farmers to prices and other related factors: Evidence from Sierra Leone rice cultivation. *International Journal of Social, Behavioral, Educational, Economics and Management Engineering. 8(3), 683-691.*

Denton, F. T., Azogu, I. I. & Ukoll, M. K. (2004). Cassava based recipes for house hold utilization and income generation. AIDU, Federal Department of Agriculture, Abuja, Nigeria.

De Menezes, T. A., & Piketty, M. G. (2012). Towards a better estimation of agricultural supply elasticity: the case of soya beans in Brazil. *Journal of Applied Economics. 44(31), 4005–4018.*

Dickey, D.A. & Fuller, W.A. (1979). ‘’ Distribution of estimates for autoregressive time series with a unit root’’. *Journal of the American Statistical Association, 74(2), 427-431.*

Dilshad, A., Muhammad, I. C. & Asad, A. H. (2017). Major crops forecasting area, Production and yield evidence from agriculture Sector of Pakistan. *Sarhad Journal of Agriculture, 33(3), 385-396.*

Eboh E.C., Oji O. K., Amakom U.S, & Uja O. C. (2004). "Towards the ECOWAS Common agricultural policy framework: Nigeria Case Study and Regional Analysis" Report submitted to Associates for International Resources and Development (AIRD) Cambridge, USA, for USAID, For USAID/West Africa.

Eke-okoro, O.N., Ekwe, K.C. & Nwosu, K.I. (2005). Cassava stem and root production. National Root Crop Research Institute Practical Manual. pp 1-52.

Eke-okoro, O.N. & Njoku, D.N. (2012). A Review of Cassava Development in Nigeria from 1940-2010: Asian Research Publishing Network (ARPN). *Journal of Agricultural and Biological Sciences, 7(1), 56-73.*

FAO (2004). Online Statistical Database. Rome, Italy: Food and Agriculture Organisation of the United Nations, website www.fao.org..

FAOSTAT (2012): Online Statistical Database. Rome, Italy: Food and Agriculture Organisation of the United Nations, website www.fao.org.a

FAO (2013). Monitorimg African Food and Agricultural Policy. Food and Agricultural Organisation Lessons Learned Report. pp 1-52

FAOSTAT (2013): Analysis of Incentives and Disincentives for Cassava Production in Nigeria: Technical Note Series, MAFAP, FAO, Rome.

FAOSTAT (2015): Online Statistical Database. Rome, Italy: Food and Agriculture Organisation of the United Nations, website www.fao.org.a

Fuller, W.A. (1969). Grafted polynomials as approximating functions. *American Journal of Agricultural Economics, 53, 35-46.*

Gardner, B. L. (1976). Future prices in supply analysis. *American Journal of Agricultural Economics, 58(1), 81-84.*

Ghosh, K. B. (2010). Growth and variability in the production of crops. *West Bengal Agriculture Trends in Agricultural Economics. 3, 135-146.*

Gujarati, D. N. (1995). *Basic econometrics* (3rd ed.). New York, Mcgraw Hill.

Harris, R. D. & Nguyen, A. (2013). Long memory conditional volatility and sset allocation. *International Journal of Forecasting, 29(2), 258-273.*

Hausman, C. (2012). Biofuels and land use change: Sugarcane and soybean acreage response in Brazil. *Environmental and Resource Economics Journal, 51(2), 163-187.*

Huang, H., & Khanna, M. (2010). An econometric analysis of US crop yield and cropland acreage: implications for the impact of climate change. Paper presented at the Agricultural Applied Economics Association: Denver, Colorado, July 25-27, 2010.

Hendricks, N.P., (2013.). The environmental effects of crop price increases: nitrogen losses in the U.S. Corn belt. *Journal of Environmental Economics and Management, 68(3), 507-526*

Hertel, T. W. (2011). The global supply and demand for agricultural land in 2050: A perfect storm in the making? *American Journal of Agricultural Economics, 93*(2), 259-275.

Hummel, I. (2010.). Arabidopsis plants acclimate to water deficit at low cost through changes of carbon usage: An Integrated perspective using growth, metabolite, enzyme and gene expression analysis. *Journal of Plant Physiology, 154(1), 357-372.*

Ifeanyi, A., Tarawali, G., Nze, L., Ogundijo, D., Edet, M., Audu, B. & Adenekan, S. (2017). Root supply response for smallholder farmers supplying to commercial starch processors in Nigeria. *Asian Journal of Rural Development, 7(1), 1-14.*

IFAD, (2004): *The global cassava development strategy:* A Cassava industrial revolution in Nigeria. The potential for a new industrial crop. Philips, T.P., Tailor, D. S., Sani, L. And Akoroda M.O. (eds). International funds for Agricultural Development, Food and Agriculture Organisation of the United Nation, Rome.

Iganga, B. O. & Unemhilin, D. O. (2011). The impact of federal government agricultural expenditure on agricultural output in Nigeria. *Journal of Economics, 2(2), 81-88.*

IITA (2004). Nigerian Cassava Industry: Statistical Handbook.

IITA, (2009). Processing potential for cassava production growth in sub-Saharan Africa. COSCA working paper No 11, Collaborative Study of Cassava in Africa, Nigeria.Index Mundi, (2015).

Ime, O.U. (2014). Aggregate agricultural output supply response in Akwa Ibom State of Nigeria: An Application of the Nerlovian Adjustment Model. *Journal Agriculture and Veterinary Science, 7(9), 24-33*

Johansen, S. (1988), A statistical analysis of co-integration vectors. *Journal of Economic Dynamics and Control, 12(.2-3), 231-54.*

Iyagba, A. G. & Anyanwu, S. O. (2012). Problems and prospects of cassava production in Rivers State, Nigeria: A case study of Oyigbo local government area. *Agriculture and Biology journal of North America, 3(7), 296-301.*

Johansen, S. and Juselius, K. (1990). Maximum likelihood and inference on co- integration with applications to the demand for Money, *Oxford Bulletin of Economics and Statistics, 52, 169-210.*

Joshua, O. A. (2010): *Supply Response, Risk and Institutional Change in Nigeria Agriculture.* African Economic Research Consortium, research paper 197, Nairobi, Kenya. Regal press (K) limited.

Juselius, K. (2006). The co-integrated VAR model: Methodology and applications, Oxford University Press (manuscript).

Kanwar, S., & Sadoulet, E. (2008). Dynamic output response revisited: The Indian Cash Crops. *Journal of Developing Economies, 46(3), 217-241.*

Kenyon, L., Anadajayasekeram, P. & Ochieng, C. (2006). "A synthesis/lesson-learning study of the research carried out on root and tuber crops commissioned through the DFID RNRRS research programmes between 1995 and 2005". Retrieved from http://www.assets.publishing.service.gov.uk.pdf

Kirtti, A. & Goyari,T. (2013). Agricultural productivity trends in India: Sustainability issue. *Agricultural Economics Review, 1(2), 71-88.*

Lambert, D. M., Xu, W. & Florax, R .J. (2012). Partial adjustment analysis of income and jobs, and growth regimes in the Appalachian region with smooth transition spatial process models. *International Regional Science Review*

Leaver, R. (2004). Measuring the supply response function of tobacco in Zimbabwe. *Agrekon, 43(1), 113-131.*

Library of Congress, (2006). Country Profile Nigeria. Federal Research Division, Library of Congress; 2006.

Lim, D. (1975). *Supply Response of Primary Producers*. Kaula Lumpur, Penerbit Univesiti Press.

Lusardi, A. & Mitchell, O.S. (2011). Financial Literacy and Planning: Implications for Retirement Wellbeing. *National Bureau of Economic Research Review.*

Mekbib, G. H. & Mathias, K. (2013). *Agricultural Supply Response to International Food Prices and Price Volatility:* A Country Panel Analysis. Selected Paper Presented at the Agricultural and Applied Economics Association's Joint Meeting, Washington, D.C. August, 2013.

Molua, E. L. (2010). Price and non-price determinants and acreage response of rice in Cameroon. *ARPN Journal of Agricultural and Biological Science, 5(3), 20-25.*

Mostofa, M. G., Karim, M. R., & Miah, M. A. (2010). Growth and supply response of winter vegetables production in Bangladesh. *Thai Journal of Agricultural Science, 43(3), 175-182.*

Mkpado, M., Arene, C. J., & Chidebelu, S. (2012). Hectarage response of rice production to market liberalisation and price risk in Nigeria. *Journal of Economic Affairs, 57(1), 73-89.*

Muchapondwa, E. (2009). Supply response of Zimbabwean agriculture: 1970-1999. *African Journal of Agricultural and Resource Economics. 3(1), 28-42.*

Muhammad, S., Muahammad F., Zahid H., Muhammad, S. & Irfan, U. (2012). Acreage response of sugarcane to price and non-price factors in Khyber Pakhtunkhwa. *International Journal of Food and Agricultural Economics. 2(3), 121-128.*

Mythili, G. (2008). *Acreage and yield response for major crops in the pre-and post-reform periods in India: A dynamic panel data approach*, Mumbai: Indira Gandhi Institute of Development Research (Report prepared for IGIDR-ERS/USDA Project: Agricultural Markets and Policy).

Najeeb, I., Khuda, B., Asif M., & Abid, S.A. (2005). Use of ARIMA model for forecasting wheat area and production in Pakistan. *Journal of Agricultural and Social Sciences. 1(2), 120- 122.*

NBS, (2011). National Bureau of Statistics survey on Agricultural indicators at a glance.

Nerlove, M. (1958). Distributed lags and estimation at long-run supply and demand elasticities theoretical considerations. *Journal of Farm Economics, 40 (3), 301 – 311*

Nerlove, M. (1959).The Dynamics of Supply: Estimation of Farmers Response to Price (Baltimore, United States of America, The Johns Hopkins Press. *American Journal of Agricultural Economics, 41(2), 452-455.*

Nerlove, M. (1979): The Dynamics of Supply: Retrospect and prospect, *American Journal of Agricultural Economics, 61(5), 874-888.*

Nkang M. Nkang , Daniel S. Udom & Sylvester O. Abang. (2006). Staple food policy and supply response in Nigeria: A case of cassava. *Journal of Food, Agriculture and Environment, 4(2), 143-146.*

Nmadu, J.N. (2002). Analysis of Sorghum Production Trend in Nigeria and Its Estimation Functions. Unpublished PhD Thesis.

Nmadu, J.N., Yisa, E.S. & Mohammed, U.S. (2009). Spline Functions: Assessing their forecasting consistency with changes in the type of model and choice of joint points. *Journal of Trends in Agricultural Economics, 2(1), 17-27*

Nmadu, J, N,, Jacob, A. T. & Baba, K.M. (2015). Growth rate and doubling time of Yam and Cassava production in Nigeria. *Russian Journal of Social Science, 12(48), 43-48*

Nmadu, J. N. (2010). Revision of the Nerlovian partial adjustment framework and its application to sorghum production in Nigeria. *African Journal of Agricultural Research, 5(5), 325-331.*

Odedokun, V. O. (2014). Application of grafted polynomial function in forecasting cotton production trend: a step towards a sustainable cotton industry in Nigeria. *Journal of Agriculture, Forestry and Social Science, 12(1).*

Odedukun, V. O., Ahamed, B., Omolehin, R. A. & Atala, T. K. (2013).Application of grafted polynomial Model as approximating functions in forecasting Cotton production trend in Zamfara State, Nigeria (1995-2013*). International Journal of Current Research and Review, 7(16), 68-73.*

Ogundameru, A. & Okewo, T. A. (2013): Resource Utilization Behaviour of Cassava Producers in Epe Area of Lagos State: Stochastic Frontier Production function Approach. Invited paper presented at the 4th international conference of African Socitety of Agricultural Economist, September, 22-25, 2013, Hammamet, Tunusia.

Ogundari, K. (2016). Maize supply response to price and non-price determinants in Nigeria: Bound testing approach: *International journal of transaction in operational research, 25(5), 1537-1551.*

Olawando, J., Margaret, N. & Wilson, N. (2009). Supply responsiveness of Maize farmers in Kenya. Paper presented at the International Association of Agricultural Economists Conference, Beijing, China. August 16-22, 2009.

Olayiwola O. (2014). Short term market forecast for cassava crops in Oyo State, Nigeria. *Journal of Agriculture and Food Technology, 4(9), 11-18.*

Onwumere, J & Ichie, V. A., (2014). Response of Nigerian cassava expansion initiatives to climate changes, economic growth and some policy instruments, 1970-2012. *International journal of food and agricultural economic, 1(2), 65-72.*

Oyewumi, O., Abiodun, O. & Andre, J. (2011). Supply response of beef in South Africa using error correction model. *Agrekon journal, 50(2), 44-58.*

Pao, H. T. & Tsai, C. M. (2011): Modeling and forecasting the carbondioxide emissions, energy consumption and economic growth in Brazil. *Energy, 36(5), 2450-2458.*

Pasarin H. & Shin Y. (1998). Generalized impulse response analysis in linear multivariate models. *Economics Letters, Elsevier, 58(1), 17-29.*

Phiko, K. (2013). Maize Hectarage response to price and non-price incentives in Malawi. *Journal of Economics and sustainable development, 4(5), 2222-2855.*

Phillip, D. A. (1988). Modelling the acreage response of Nigerian cotton growing farmers under a modified formulation of adaptive price expectation hypothesis. *Oxford Agrarian Studies Journal, 17(1), 55-162.*

Phillip, D. A. (1990). Grafted polynomials as forecasting functions: Application to Cotton production in Nigeria. *Savanna Journal, 11(1), 491-495.*

Potgieter, A. (2010). Early-season crop area estimates for winter crops in North East Australia using MODIS satellite imagery. *ISPRS Journal of Photogrammetric and Remote Sensing, 65(4), 380-387.*

Richards, P. D., Myers, R. J., Swinton, S. M., & Walker, R. T. (2012). Exchange rates, soybean supply response, and deforestation in South America. Global Environmental Change, 22(2), 454-462.

Roberts, M. J., & Schlenker, W. (2009). World supply and demand of food commodity calories. *American Journal of Agricultural Economics, 91(5), 1235-1242.*

Roberts, M. J., & Schlenker, W. (2010). The US biofuel mandate and world food prices: an econometric analysis of the demand and supply of calories. Paper presented at the NBER Meeting on Agricultural Economics and Biofuels, Cambridge, MA, March 4 - 5, 2010.

Saleem A, Irum, R, Alamgir, K. M. Nisar, K, Saqib, A. M. & Asif, M. (2014). Trend analysis and forecasting of maize area and production in Khyber Pakhtunkhwa, Pakistan. *European academic research journa, 2(4), 4653-4664*

Sanzidur R. & Brodrick O. A. (2016). Exploring the potential of cassava in promoting agricultural growth in Nigeria. *Journal of Agriculture and Rural Development in the Tropics and Subtropics. 117 (1), 149–163*

Sanderson, B. A., Quilkey, J. J., & Freebairn, J. W. (2012). Supply response of Australian wheat growers. *Australian Journal of Agricultural and Resource Economics, 24(2), 129-140.*

Schreinemachers, P. & Berger, T. (2011). An agent-based simulation model of human environment interactions in agricultural systems. *Environmental Modeling and Software, 26(7), 845-859. DOI:10.1016/Jenvsoft201102.004*

Shittu, M. A., Ajuwon, O. S. & Kehinde, O. (2012). *Economics for Schools, (*1st ed.) Sango Otta, Nigeria. Melrose Publishers.

Silvapulle, P. & Jayasuriya, S. (1994). Testing for Philippines rice market integration: A Multiple Co-integration Approach, *Journal of Agricultural Economics. 45(3), 369-380.*

Sims C.A. (1980). Macroeconomics and reality. *Econometrica Journal, 48(1), 1-48.*

Smith; G; Van V; Obersteiner; H. & Rounsevell. (2010). Competition for land Philosophical Transactions of the Royal Society: *Journal of Biological Sciences, 365(1554), 2941-2957.*

Subervie, J. (2008). The variable response of agricultural supply to world price instability in developing countries. *Journal of Agricultural Economics, 59(1), 72-92.*

Suleiman, N. & Sarong S. (2012). Forecasting milled rice production in Ghana using Box-Jenkins approach. *International Journal of Agricultural Management and Development, 2(2), 79-84.*

Tesfaye, T, Getahun, D, Ermias. S, Shiferaw, M, Temesgene, A, & Birhanu, Y. (2013). Current status, Potentials and challenges of Cassava production, processing, marketing and utilization: Evidence from Southern Ethiopia. *Greener Journal of Agricultural Sciences, 3 (4), 262-270.*

Tesfaye, T., Getahun, D., Ermias, S., Shiferaw, M. , Temesgene, A. & Birhanu, Y. (2016). Performance of cassava clones under potential and low moisture stressed area of Ethiopia. *Applied Sciences Report, 13(1), 12-19.*

Udu, E. & Agu, G.A. (2013). *New Systems Economics. A Senior educational Course.* Onitsha, Nigeria. Africana First Publishers.

Umanah E. E. (1977). Cassava research in Nigeria before 1972. In: Proceedings, fourth symposium of the International Society for Tropical Root Crops, edited by J. Cock, R.Machntyre and M. Graham IDRC - 080e: Ottawa.

UNIDO, (2006): Nigeria Cassava Master Plan: A strategic action plan for the development of the Nigerian cassava industry.

VanRompay, T. J. & Pruyn, A. T. (2011). When Visual Product Features Speak the Same Language: Effects of Shape-Type face Congruence on Brand Perception and Price Expectations. *Journal of Product Innovation Management, 28(4), 599-610.*

Vitale, J. D., Djourra, H., and Sidib, A. (2009). Estimating the supply response of cotton and cereal crops in smallholder production systems: recent evidence from Mali. *Agricultural Economics Journal, 40(5), 519-533.*

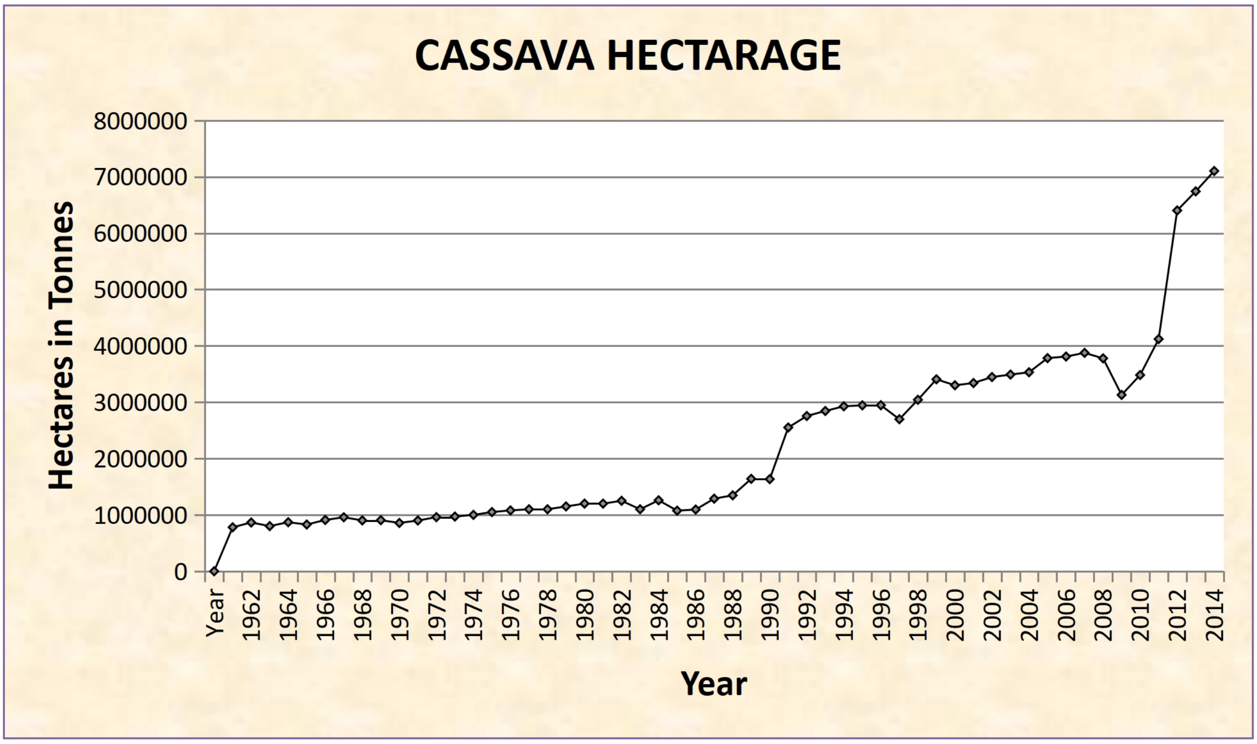
Weersink, A., Cabas, J. H., & Olale, E. (2010). Acreage Response to Weather, Yield, and Price. *Canadian Journal of Agricultural Economics/Revue canadienned' Agro economie, 58(1), 57-72.*

Yu, B., & Fan, S. (2011). Rice production response in Cambodia. *Agricultural Economics Journal, 42(3), 437-450.*

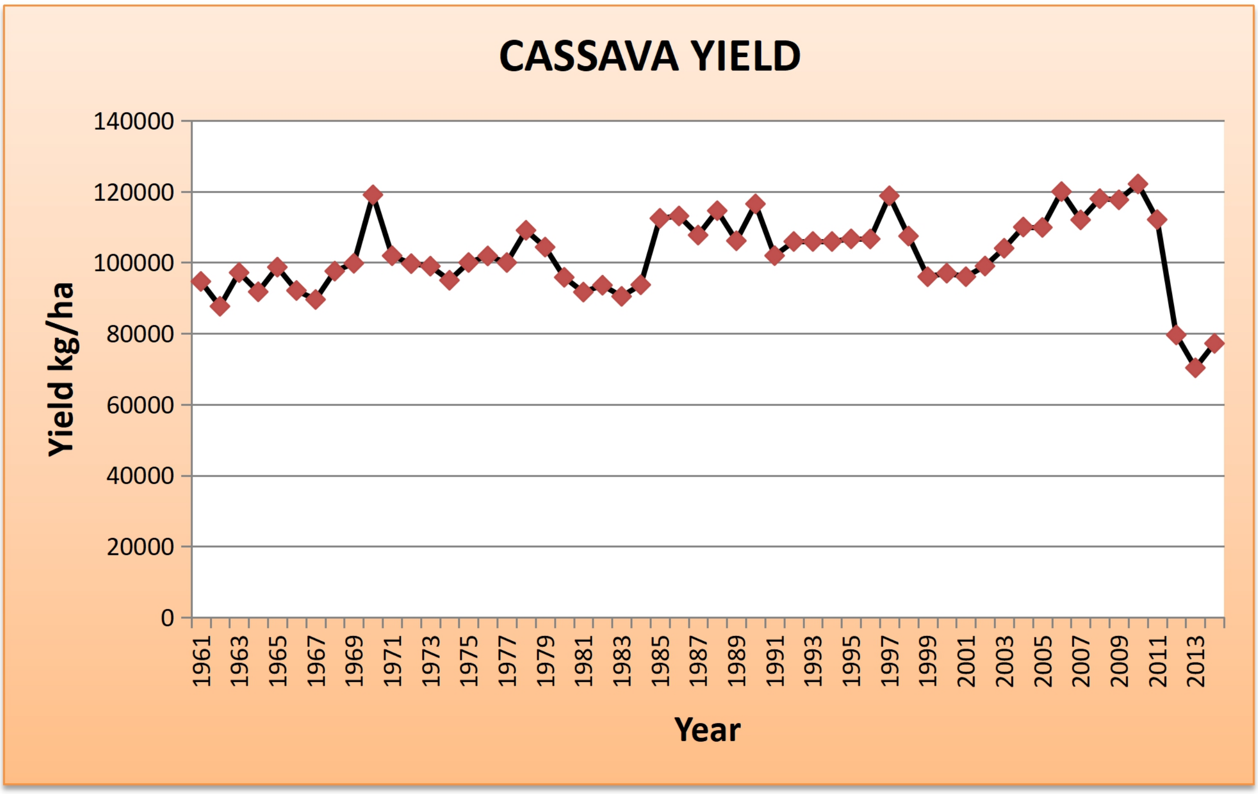
Yu, B., Liu, F., and You, L. (2012). Dynamic agricultural supply response under economic transformation: A Case Study of Henan, China. *American Journal of Agricultural Economics, 94(2), 370-376*

Zhao, H. (2010). Dynamic relationship between exchange rate and stock price: Evidence from China. *Research in International Business and Finance, 24(2), 103-112. DOI:10.1016/j ribaf2009.09.001*

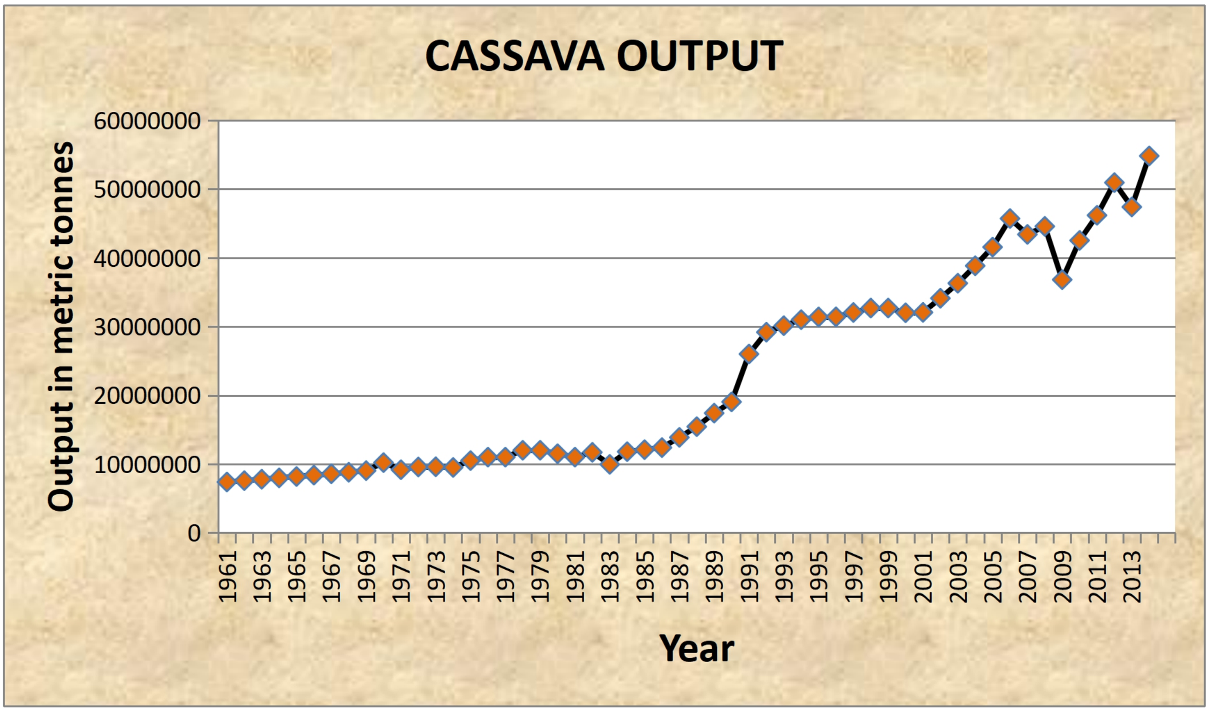
Appendices



Appendix A: Graphical representation of cassava hectarage in '000 hectares in Nigeria, 1961-2014



Appendix B: Graphical representation of cassava yield kg/ha in Nigeria, 1961-2014.



Appendix C: Graphical representation of cassava output in '000 metric tonnes in Nigeria, 1961-2014.

Appendix D: Estimates of the coefficients of partial adjustment and adaptive expectation Models

year	Partial adjustment	Adaptive expectation
1963	6.55E-07	0.521929403
1964	6.03E-07	-0.011867025
1965	5.81E-07	-0.032685514
1966	6.02E-07	-0.033572606
1967	5.73E-07	-0.037403192
1968	6.34E-07	-0.390036022
1969	5.85E-07	-0.093523856
1970	5.61E-07	-0.192437688
1971	5.86E-07	-0.328667333
1972	5.78E-07	-0.297900536
1973	5.71E-07	-0.619155642
1974	5.79E-07	-0.356489403
1975	5.86E-07	-0.237279663
1976	5.72E-07	-0.189396312
1977	5.95E-07	-0.612484517
1978	5.45E-07	-0.123601092
1979	5.89E-07	-0.187017649
year	**Partial adjustment**	**Adaptive expectation**
1981	6.00E-07	-0.542975774
1982	5.72E-07	-0.61261175
1983	5.82E-07	-1.172083878
1984	5.47E-07	-0.511066413
1985	5.71E-07	-0.722809119
1986	5.21E-07	-0.518525477
1987	5.39E-07	-0.463202744
1988	5.18E-07	-0.251779171
1989	5.21E-07	-0.595407589
1990	5.14E-07	-0.475800093
1991	5.35E-07	-0.359914161
1992	5.14E-07	-0.355541171
1993	5.31E-07	-0.085104739
1994	5.26E-07	0.151240995
1995	5.31E-07	-0.089551533
1996	5.13E-07	0.146457879
1997	4.49E-07	-0.013186934
1998	4.35E-07	-0.190489753
1999	3.39E-07	-0.231994977
2000	3.83E-07	-0.239936966
2001	3.68E-07	-0.503858666
2002	2.84E-07	-0.27207541
2003	4.17E-07	0.51012543

2004	4.72E-07	-0.087612238
2005	2.28E-07	-0.573826297
2006	2.38E-07	-0.051552382
2007	2.44E-07	0.003946914
2008	2.05E-07	0.002650688
2009	1.21E-07	-0.404267696
2010	8.16E-08	-0.156836009
2011	2.29E-07	-0.366534652
2012	2.81E-07	-0.502607949
2013	1.86E-07	-0.129829605
2014	2.00E-07	-0.167567626
mean	**4.69E-07**	**-0.256186542**

Source: Computer result output, 2019.

Appendix E: Estimates of short run and long run elasticities of cassava supply from partial adjustment and adaptive expectation models

	Partial adjustment		Adaptive expectation	
year	short run	long run	short run	long run
1963	-3.00E-16	-4.59E-10	1.90E-03	0.003643097
1964	-2.64E-16	-4.38E-10	-4.13E-05	0.003478390
1965	-2.77E-16	-4.76E-10	-1.24E-04	0.003780793
1966	-2.61E-16	-4.34E-10	-1.16E-04	0.003444261
1967	-2.52E-16	-4.40E-10	-1.31E-04	0.003497322
1968	-2.97E-16	-4.68E-10	-1.45E-03	0.003714451
1969	-2.19E-16	-3.75E-10	-2.79E-04	0.002982300
1970	-1.60E-16	-2.86E-10	-4.37E-04	0.002270028
1971	-3.72E-16	-6.35E-10	-1.66E-03	0.005043665
1972	-6.31E-16	-1.09E-09	-2.58E-03	0.008668800
1973	-5.29E-16	-9.26E-10	-4.55E-03	0.007353798
1974	-4.18E-16	-7.21E-10	-2.04E-03	0.005728163
1975	-4.86E-16	-8.29E-10	-1.56E-03	0.006587645
1976	-6.63E-16	-1.16E-09	-1.74E-03	0.009206691
1977	-7.35E-16	-1.24E-09	-6.02E-03	0.009825322
1978	-7.42E-16	-1.36E-09	-1.34E-03	0.010807854
1979	-7.67E-16	-1.30E-09	-1.93E-03	0.010337948
1980	-1.56E-15	-2.61E-09	-5.51E-03	0.020715054
1981	-2.04E-15	-3.40E-09	-1.47E-02	0.027019636
1982	-2.61E-15	-4.57E-09	-2.22E-02	0.036314391
1983	-3.10E-15	-5.32E-09	-4.95E-02	0.042248886
1984	-2.54E-15	-4.65E-09	-1.89E-02	0.036913244
1985	-4.12E-15	-7.21E-09	-4.14E-02	0.057306763
1986	-1.11E-15	-2.14E-09	-8.80E-03	0.016976721
1987	-1.76E-15	-3.26E-09	-1.20E-02	0.025928781
1988	-2.13E-15	-4.10E-09	-8.20E-03	0.032576013
1989	-3.41E-15	-6.54E-09	-3.09E-02	0.051937453
1990	-6.21E-15	-1.21E-08	-4.56E-02	0.095900503
1991	-3.88E-15	-7.25E-09	-2.07E-02	0.057619295
1992	-5.25E-15	-1.02E-08	-2.88E-02	0.081049101
1993	-5.94E-15	-1.12E-08	-7.57E-03	0.088925385
1994	-1.13E-14	-2.16E-08	2.59E-02	0.171330525
1995	-1.09E-14	-2.06E-08	-1.46E-02	0.163366007
1996	-1.57E-14	-3.05E-08	3.55E-02	0.242498024
1997	-2.40E-14	-5.33E-08	-5.58E-03	0.423515317
1998	-2.31E-14	-5.30E-08	-8.03E-02	0.421302067
1999	-1.56E-14	-4.60E-08	-8.47E-02	0.365233132
2000	-2.15E-14	-5.62E-08	-1.07E-01	0.446069629
2001	-2.15E-14	-5.83E-08	-2.33E-01	0.463281594
2002	-2.05E-14	-7.23E-08	-1.56E-01	0.573951644

2003	-3.75E-14	-9.00E-08	3.65E-01	0.714742925
2004	-4.01E-14	-8.48E-08	-5.90E-02	0.673692655
2005	-1.59E-14	-6.96E-08	-3.17E-01	0.552680870
2006	-1.87E-14	-7.83E-08	-3.21E-02	0.621806220
2007	-2.07E-14	-8.46E-08	2.65E-03	0.671899907
2008	-1.62E-14	-7.91E-08	1.67E-03	0.628217268
2009	-1.77E-14	-1.46E-07	-4.70E-01	1.162152715
2010	-5.74E-15	-7.03E-08	-8.75E-02	0.558101103
2011	-1.62E-14	-7.07E-08	-2.06E-01	0.561618546
2012	-1.32E-14	-4.70E-08	-1.88E-01	0.373092366
2013	-8.98E-15	-4.83E-08	-4.98E-02	0.383492618
2014	-9.62E-15	-4.81E-08	-6.40E-02	0.381956756
mean	**-8.41E-15**	**-2.74E-08**	**-3.97E-02**	**0.217803916**

Source: Computer result output, 2019.