AGGREGATE COCOA SUPPLY RESPONSE TO GOVERNMENT EXPENDITURE IN GHANA

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ABSTRACT

The cocoa sub-sector of Ghana is a major employer and source of income for most smallholder farmers as well as a major export earner for the government. The importance of the cocoa sub-sector has resulted in government committing over 50% of agricultural expenditure to the sub-sector in an attempt to increase annual output. Despite the large share of government agricultural expenditure on the sub-sector, studies have found the productivity level in the cocoa sub-sector to be amongst the lowest in the world. This study was conducted to find out how responsive cocoa supply was to government expenditure on the sub-sector. Specifically, the objectives of the study were to explore the composition of expenditure on non-research activities and then to determine the responsiveness of cocoa supply to research and non-research expenditures. The study employed the vector error correction model, using time series data from 1996 to 2016 to estimate both the short- and long-run elasticities. Results show that in terms of composition and pattern of non-research expenditure, larger share was dedicated to administrative work while training of field and technical staff received the least expenditure over the study period. Further, the findings show that expenditure on research positively impacted the level of cocoa supply in both the short- and long-run. Non-research expenditure on the contrary had a negative effect on cocoa supply in the short-run but showed a positive effect in the long-run. The empirical results showed that cocoa supply was more responsive to research expenditure than to non-research expenditure. The study recommends the need for increased research expenditure and the need for right targeting of non-research expenditure to ensure the best possible aggregate cocoa supply response.

DECLARATION

I, **Atta-Aidoo, Jonathan**, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor concurrently being submitted for a higher degree in any other institution.

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DEDICATION

This work is dedicated to Wamunyima Marah Libakeni, the future holds no limit.

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LIST OF ABBREVIATIONS AND SYMBOLS

ADF	Augmented Dickey-Fuller
BCC	Bonsu Cocoa College
CAADP	Comprehensive Africa Agriculture Development Programme
CHED	Cocoa Health and Extension Division
CMC	Cocoa Marketing Company
COCOBOD	Ghana Cocoa Board
CPI	Consumer Price Index
CRIG	Cocoa Research Institute of Ghana
CRIG	Cocoa Research Institute of Ghana
CSD	Cocoa Service Division
CSSVD	Cocoa Swollen Shoot Virus Disease Control Unit
ECM	Error Correction Model
ECT	Error Correction Term
FAO	Food and Agriculture Organisation of United Nations
FAOSTAT	Food and Agriculture Organisation Corporate Statistical Database
FOB	Free-On-Board
GDP	Gross Domestic Product
GHS	Ghana Cedis
GSS	Ghana Statistical Service
GOV	Other Government Policies
H-O	Head Office
ICCO	International Cocoa Organisation
K-Exp	Capital Expenditure

mm	Millimetres
MT	Metric Tonnes
OLS	Ordinary Least Squares
PIV	Price Difference between Ivory Coast and Ghana Cocoa
PPRC	Producer Price Review Committee
R&D	Research and Development
QCC	Quality Control Company
SPD	Seed Production Division
SPD	Seed Production Division
SPU	Seed Production Unit
VECM	Vector Error Correction Model
WB	World Bank

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Globally an estimated 14 million people are engaged in cocoa production of which 75% are in Africa (Nunoo *et al*., 2013). Cocoa is a cash crop which is mostly cultivated in the humid tropics of West and Central Africa, South-East Asia, South-America and the Caribbean (Owusu and Frimpong, 2014). West and Central Africa account for 70% of the world's cocoa (Hutchins *et al*., 2015).

In Ghana, an estimated 865 000 smallholder farmers are engaged in cocoa farming with an additional 2 million people benefiting from the sub-sector through employment (Gakpo, 2012). Cocoa is Ghana’s second largest export earner accounting for close to 30% of total export earnings and more than 50% of agricultural export earnings (Aziz *et al*., 2017; Hutchins *et al.*, 2015).

Ghana was the leading world producer of cocoa beans between the period of 1911 and 1976 (Darkwah and Verter, 2014) but lost this leadership to Ivory Coast and now stands as the second largest supplier of cocoa in the world (Onumah *et al*., 2014; WB 2017; Wessel and Quist-Wessel, 2015). Cocoa output has been fluctuating annually but recorded a steady rise from 300 000 metric tonnes (MT) in 1995 to a record high of over 1 million MT in the 2010/11 season (Hutchins *et al.*, 2015) before recording negative growth rates afterwards (Wessel and Quist-Wessel, 2015). The growth rate recorded for cocoa peaked at 26 % in 2010 but recorded negative growth rates in 2012, 2015 and 2016 (GSS, 2018; WB, 2017).

The cocoa sub-sector of Ghana over the years continue to be favoured in agricultural policy and budget allocation. Benin (2017) reported that, between 1958 and 2013, agricultural expenditure on the cocoa sub-sector grew at an average rate of 3.7 % per year. Such expenditure on the cocoa sub-sector has been very high relative to the value of cocoa production. For instance, in 2006 and 2011, the share of public agricultural spending devoted to the cocoa sub-sector averaged three times the sub-sector's share in total agricultural output (WB, 2013). Given the high levels of government agricultural expenditure continually been allocated to the cocoa sub-sector, one would have expected increasing productivity and hence greater output levels in cocoa but this has not been the case.

1.2 Problem Statement and Justification

Bateman (1965) was the first to model the supply response of cocoa in Ghana and indicated that as in line with economic theory, the supply of cocoa responded strongly to the prices of cocoa and coffee, taking coffee as an alternative means of farmer investment to cocoa. Bateman (1965) indicated that rainfall also affected the supply of cocoa. The strong impact cocoa price has on cocoa output was confirmed by Ankrah (2014), who indicated the positive impact cocoa prices have on the level of cocoa output in Ghana. Bulir (1998) argued that international prices and the price incentive to smuggle cocoa explain more of the fluctuations experienced in annual cocoa supply than all other variables. This was evident in the high speed of adjustment to long-run price changes. The size of cocoa area harvested, real GDP per capita and cocoa export levels are all positively related to cocoa output (Darkwah and Verter, 2014).

As indicated by Kolavalli and Vigneri (2017), cocoa output in Ghana has been closely related to movements in producer prices, although short-term fluctuations in output may also be due to other factors. Kolavalli and Vigneri (2017) pointed out that, the real producer price of cocoa in Ghana tripled between the period 1981 and 1988 as well as recording a sevenfold increment in nominal price during the 16-year period of 1996/1997 to 2012/2013. Such increment in producer prices has been associated with the cocoa farmers' willingness to maintain and expand their cultivation of cocoa since cocoa remains relatively profitable.

Chandio *et al*. (2016) observed that government agricultural expenditure had a positive and significant impact on agricultural output. This was a confirmation of an earlier study by Fan *et al*. (2003) who indicated that overall agricultural expenditure had a positive impact on agricultural GDP but on a disaggregated level, expenditure on agricultural research was more impactful. Further evidence shows that agricultural public expenditure is estimated to have a positive impact on agricultural productivity which in turn increases overall agricultural output (Benin *et al*., 2012; Wangusi and Muturi, 2015).

However, contrary to the findings reported by the aforementioned authors, and despite expenditure on the cocoa sub-sector accounting for up to 50% of overall agricultural expenditure (Benin, 2017; WB, 2017). Estimated productivity in the cocoa sub-sector of Ghana is among the lowest in the world with a potential of doubling output given improvement in productivity (WB, 2017). Although there is the potential of doubling output, current returns of cocoa to government expenditure stands at a low of 11% (Benin 2016, 2017).

Studies done so far (Ankrah *et al.*, 2014; Bateman, 1965; Bulir, 1998; Darkwah and Verter, 2014) have contributed to understanding how the supply of cocoa in Ghana respond to factors such as producer and international price of cocoa, price of alternative crops, rainfall, size of cocoa area harvested, exports and the incentive to smuggle cocoa outside of the country. Given the large share of agricultural expenditure going to the cocoa sub-sector and the existing body of knowledge providing insight as to how cocoa responds to all relevant factors except the expenditure on the sub-sector. This study is an attempt to provide empirical understanding of how responsive the supply of cocoa is to government expenditure and therefore, provide policy makers with information on which spending cocoa supply is more responsive to.

1.3 Objectives of the Study

1.3.1 General Objective

To examine the composition of government's non-research expenditure and the responsiveness of cocoa supply to government's agricultural expenditure.

1.3.2 Specific Objectives

i. To examine the composition of government's non-research expenditure on the cocoa sub-sector.

ii. To analyse the responsiveness of cocoa supply to government's expenditure on research in the cocoa sub-sector.

iii. To analyse the responsiveness of cocoa supply to government's expenditure on non-research activities in the cocoa sub-sector.

1.4 Research Question

What are the components of government's non-research expenditure on the cocoa sub-sector.

1.5 Hypotheses of the Study

1. Cocoa supply does not respond to government expenditure on research in the cocoa sub-sector.
2. Cocoa supply does not respond to government expenditure on non-research activities in the cocoa sub-sector.

1.6 Organisation of the Dissertation

This dissertation is organised into five chapters. Chapter one presents the background, problem statement and justification, research objectives, question and hypotheses. Chapter two presents the management structure of the cocoa sub-sector in Ghana, theoretical and empirical literature as well as description and choice of variables. Chapter three presents the conceptual and theoretical frameworks, analytical procedure for analyses, sources and nature of data used and section the study area. Chapter four presents the discussion of the results. Chapter five finally present conclusions, recommendations and limitations of the study.

CHAPTHER TWO

2.0 LITERATURE REVIEW

2.1 Management of the Cocoa Sub-Sector of Ghana

The Ghana Cocoa Board (COCOBOD) established in 1947 is tasked with managing the cocoa sub-sector of Ghana (Essegbey and Ofori-Gyamfi, 2012). COCOBOD manages the sub-sector under the authority of the Ministry of Food and Agriculture by controlling the export and internal marketing of cocoa beans and, through its subsidiaries, delivers inputs, research and extension services, pest and disease control, quality regulation and some forms of infrastructure (WB, 2017).

The operations of COCOBOD are undertaken through its five main subsidiaries. These are the Cocoa Research Institute of Ghana (CRIG), Seed Production Division (SPD), Cocoa Health and Extension Division (CHED), Quality Control Company (QCC) and Cocoa Marketing Company (CMC). CRIG is tasked with research that will ensure optimal yields. SPD ensures the mass production and distribution of high-quality planting materials in the most resourceful and cost-effective way in sufficient amounts to farmers. CHED is in charge of controlling the cocoa swollen shoot virus disease, restoration of old and unproductive cocoa farms and extension services. The remaining two subsidiaries engage in post-harvest activities of COCOBOD. QCC is responsible for inspection and grading while CMC is responsible for procuring, carriage, storage and marketing of cocoa, both internally and externally (COCOBOD, 2019).

2.2 Theoretical Review

The theory underlying this study is the multi-period theory of the firm. The aim of the farmer given alternative modes of resource allocation will be to maximise the present value of his profit from production subject to the technical constraints imposed by his production function (Henderson and Quandt, 1971). Determining the optimal decisions on planting perennial crops depend on the link between relative prices of the output and the fraction of the marginal products of constrained fixed resources (Peralta and Swinton, 2015).

2.3 Theoretical Framework

A representative cocoa farmer is assumed to maximise accrued wealth over a multi-period time limit as a function of the production of cocoa subject to the available resources. Following Berry (1976), available resources and current opportunity cost were the main drivers of farmers' annual planting decision of cocoa. Therefore, production decision of a cocoa farmer is dependent on the availability of land, labour and working capital.

The production function of a cocoa farmer is then given implicitly as:

$$F(Q_t; L_t, N_t, K_t) = 0 \quad \text{.......} \quad (1)$$

Where;

$$L_t = L_C + L_O + L_M \quad \text{.......} \quad (2)$$

$$N_t = N_C + N_O + N_M \quad \text{.......} \quad (3)$$

And $K_t = K_C + K_O + K_M$ .... (4)

Where: Q is cocoa output, L is amount of land, N is labour requirement, K is the available working capital. The subscript "t" refers to the time period considered and the subscript (C, O, M) refer to the share of the inputs allocated to cocoa, oil palm and maize production respectively.

The constrained profit maximisation of a cocoa farmer will then be given as:

$$\pi_t^* = \sum_{t=1}^{T} \beta_t\{P_tQ_t(.) - R_tL_t - W_tN_t - I_tK_t\} + \lambda F(Q_t; L_t, N_t, K_t) \quad \text{.......} \quad (5)$$

where

$t = 1, \ldots, T$,

$\beta_t = \frac{1}{1+\varepsilon t}$ …………………………………………………………………………….. (6)

and

$\varepsilon_t = (1 + i)^{\tau - t} - 1$ ……….……………………………………………………………… (7)

For β_t is the discount rate, ε_t is the rate of return and i is the interest rate and R, W and I are the returns to land, labour and capital (rent, wage and interest) respectively.

The first order condition gives;

$\partial\pi_t^*/\partial Q_t = P_t\beta_t + \lambda.\partial F/\partial Q_t$ ………………………………………………………………… (8)

$\partial\pi_t^*/\partial L_t = -R_t\beta_t + \lambda.\partial F/\partial Q_t$ ……………...…………………………………………….. (9)

$\partial\pi_t^*/\partial N_t = -W_t\beta_t + \lambda.\partial F/\partial Q_t$ ……………………………..……………….……….……… (10)

$\partial\pi_t^*/\partial K_t = -I_t\beta_t + \lambda.\partial F/\partial Q_t$ ………………..…………………………….…………….....… (11)

$\partial\pi_t^*/\partial \lambda = F(Q_t; L_t, N_t, K_t)$ ……………………..………………………………...........(12)

This optimisation (using the Hotelling's Lemma) then gives the profit-maximising level of output supply functions as:

$Q_t^s = Q(P_t, PC_t, PM_t, R_t, W_t, I_t\ i)$…………………………………………………… (13)

Where Q_t^s is output of cocoa supplied, P_t is the price of cocoa, PO_t is the price of oil palm, PM_t is the price of maize, R_t is rent on land, W_t is wage of labour, I_t is interest on capital and i is interest rate (all in time period t).

Subsequently, a cocoa farmer with the required inputs will be confronted with the decision as to whether to engage in cocoa production or look for alternatives of higher returns either in the short-run or the long-run which is captured in the forms of maize and oil palm prices respectively. Farmers' initial decision to adopt and subsequently plant cocoa is dependent on the advantage of cocoa relative to other productive activities (Berry 1976). Therefore, the output supply function in a multi-period framework is a function of all prices and interest rate (Henderson and Quandt, 1971).

2.4 Conceptual Framework

The researcher's perceived conceptual framework (Fig. 1) shows the relationship between the variables of interest. The diagram is a figurative representation of the interplay among variables used in this study. This shows how variables affect the output of cocoa supplied either directly or through an intermediary.

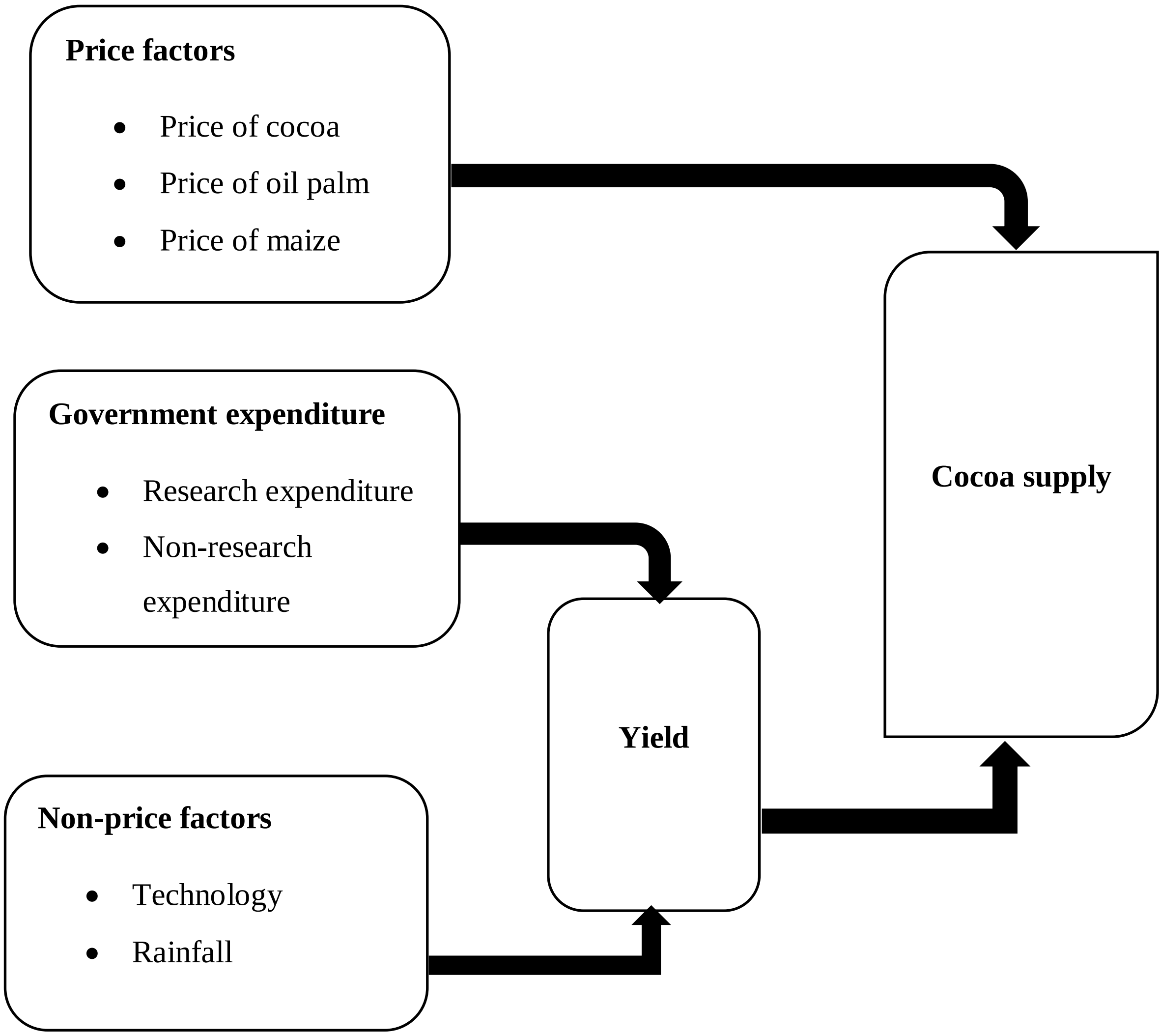

Figure 1: A conceptual framework for the supply of cocoa in Ghana

Author's own design

Conceptualized independent variables fall under three categories: price factors, government expenditure and non-price factors. The price factors were expected to affect the supply of cocoa directly. The price of coca was expected to cause a positive response from farmers by supplying more cocoa beans. The prices of maize and oil palm on the other hand were expected to cause cocoa farmers to shift resources from cocoa production, hence a negative impact on supply. The non-price factors, technology and rainfall were expected to cause changes in the supply of cocoa indirectly through their impact on yield. Favourable rainfall condition and new technology were likely to be yield-enhancing and hence have a positive impact on the supply of cocoa beans. Government expenditure on the cocoa sub-sector is categorised into research and non-research motivated expenditures. Research expenditure is geared towards improving productivity through the discovery of improved seedlings. This was expected to have a yield-improving effect which will translate into greater output supplied. Non-research expenditure such as those for extension purposes was expected to be yield-enhancing since cocoa farmers will learn of new ways to improve their output levels.

2.5 Pathways Public Agricultural Expenditure Affect Cocoa Output

Public expenditure on the cocoa sub-sector has the potential of increasing the supply of cocoa largely through improved productivity due to the limitation posed by land availability. Literature demonstrates that the productivity effects of government's agricultural expenditure manifests via several channels with different effects depending on the type of expenditure. Such effects regularly delay before occurring rather than occur contemporaneously.

Following Benin (2015, 2016) productivity effect of public expenditure on the cocoa sub-sector can be categorised into four pathways; technology advancing, human capital enhancing, transaction cost reducing, and crowding-in of private capital.

Technology-advancing productivity effects arise particularly from the yield-improving technologies of government expenditure on agricultural research and development (R&D). Some of the public expenditure on the cocoa sub-sector go into research that results in the provision of hybrids, improved fertilisers and pesticides that are more effective as well as new farm implements that make farmers more efficient.

Human-capital-enhancing productivity effects arise from government expenditure in agricultural education, extension, and information that advances the knowledge and skills of farmers. Faced with a never-ending demand for improved quality of cocoa beans and the challenges posed by new diseases and pests. Cocoa farmers are in constant need of new knowledge to deal with such challenges and as such they benefit from public expenditure that goes into agricultural education and extension services.

The transaction-cost-reducing productivity effects are anticipated to originate from government expenditure on infrastructure in the agricultural sector. These are expected to contribute to improving access to input and output markets, in so doing decreasing the cost of agricultural inputs and technologies. Expenditure on the much touted “cocoa-roads” are a means of reducing the burden of cocoa farmers in transporting their cocoa beans to the purchasing centres and cut-down on losses due to inability to access markets.

The crowding-in productivity effect of government agriculture expenditure arises from the notion that by rising the productivity of all factors in production, as explained above, a rise in government expenditure is anticipated to result in the growth of private capital to the point where public and private investments become complementary. Government expenditure on the cocoa sub-sector that alleviates or reduces the challenges faced by cocoa farmers tend to attract more private investment in the cocoa sub-sector thereby increasing supply.

2.6 Empirical Review

Mustafa *et al*. (2016) categorises the econometric approach to the analysis of agricultural supply response into three. These are the direct reduced form approach, two-stage or indirect structural form approach and the cointegration approach.

Perennial crops have four distinguishing characteristics from annual crops which have to be taken into consideration when one is interested in modelling their supply. These characteristics are that; firstly, perennial crops are a long-term investment; secondly, there exist a long gestation interval between initial planting and first harvest; thirdly, once trees start yielding, there is an extended period of productivity and then a gradual decline in production and lastly, upon reaching final productivity decline they are removed (Devadoss and Luckstead, 2010; Mustafa *et al*., 2016). The first two characteristics of perennial crops indicate that their supply is one of a dynamic nature. Therefore, to get a true representation in the case of perennial crops the supply response models must explain new plantings, rehabilitation and restoration of plants, composition of plants by their age and the delayed-effects inputs have on output (Kumar and Sharma, 2006).

To be able to account for the dynamic nature of perennial crop supply, French and Matthews (1971) proposed a structural model comprising five sets of separate equations aimed at accounting for all possibilities. These equations were; i) two equations explaining the produced quantity and the desired level of plantations by farmers, ii) a new planting equation defined by the adjustments which would shift areas towards the desired level, iii) an equation which explains the removed area each year, iv) an equation which explains relationships between unobservable and observable variables, and v) an equation which explains variation in the average yield values. To obtain the changes in annual planted area, the second and third equations relating to new planting and removals are combined. The total production is then obtained by multiplying the planting equation by the yield equation.

Following French and Matthews (1971), Laajimi *et al*. (2008) divides the product supply into two corresponding components equations representing new planting and removal and proceed to analysing supply response of peaches by estimating equations for new plantations, removals and yield before presenting in acreage equation which was deduced from the three equations earlier estimated. Devadoss and Luckstead (2010) estimated a structural model for the supply of apple. In modelling, yield was seen as dependent on expected apple price, input prices, weather factors, technology, and age distribution of bearing trees. A two-step procedure was then employed to firstly estimate the expected variables using rational expectations approach and afterwards these expected variables substituted into the structural model to estimate the endogenous variables. To ensure consistency with the rational expectation theory, all previous information was used by farmers to form expectations about their production decisions.

Elnagheeb and Florkowski (1993) observed that, the structural model approach for estimating separate equations is the best approach since it is able to provide more accurate estimates than the reduced single form equation for supply response however, the difficulty in doing so however, arises from the unavailability of data. Data limitations pertaining to removals and new plantings have made supply response studies adopt the reduced-form, single-equation approach. In this way unobserved variables are modelled as a function of observable variables such as expected price, cost and output and then substituted into other structural equations to obtain a single-equation, reduced form model. In a study by French *et al*. (1985) pertaining to perennial crop supply, difficult empirical challenges due to absent data relating to planting, removals, composition by age, and yield differences by age of plants made the authors to model through the direct estimation of a function that relates changes to total bearing area to lagged prices and costs in an attempt to overcome the data limitations.

Estimation of the supply response is done directly by including partial adjustment and expectations formation in what is known as the direct reduced form approach or

Nerlovian model approach. In this framework desired output can be stated as a function of expected price and external factors (Nerlove, 1958 as cited by Tripathi and Prasad, 2009). Agbogo and Okorie (2014) in studying the supply response of rubber indicated that, the Nerlovian approach is able of capturing the gestation period involved in all investments, the actual or realised change in output in any one period can be seen as a fraction of the desired change. Adjustment was then presumed to be gradual due to constraints on the farmer. With the issue of the dynamic nature of perennial crop supply response, Wani *et al*. (2015) modelling supply response of apple and pear explained that, the Nerlovian model approach to capture the dynamics in supply incorporates price expectations and partial area adjustments. The adjustment coefficient present in the Nerlovian model helps to capture this adjustment.

Attempting to present a more realistic behaviour of rubber farmers, Much *et at*. (2011) drew on the partial adjustment and adaptive expectations mechanisms largely embedded in the Nerlovian tradition. The study related new planted area to actual planted area in previous period and expressed new area planted as relative to the change between new and actual planted area in the immediate past by the speed coefficient of adjustment. Modelling an equation for average yield of rubber as a function of expected rubber price in coming year and other observable supply shifters, the authors assumed that farmers review the price they expect to get in the next year by using the percentage of the error that they made in forecasting for last year's price. A response model was then given as a function of one-year lag of rubber price, current alternative crop prices, actual rainfall and previous year's yield. Askari and Cummings (1976) cited in Tripathi and Prasad (2009) in attempt to address the issue of serial correlation and inconsistency of their estimates used a modified version of the Nerlovian model with maximum-likelihood estimation procedure.

Economic time series data are trended overtime and regression between trended series may produce significant results with high R^2 even though such results may be false resulting in deceptive conclusions and recommendations being made (Granger and Newbold, 1974). The Nerlovian model has no inbuilt mechanism for dealing with such trended data. Hallam and Zanoli (1993) discloses that, the partial adjustment mechanism, which is largely employed in the Nerlovian approach to supply response is a simple dynamic framework with an impractical postulation of a static target supply based on motionless expectations thereby making it limiting in the framework of optimising behaviour under dynamic circumstances such as in perennial crops supply. The Nerlovian model is unlikely to fully reveal the dynamism in agricultural supply (Thiele, 2000) and has proved to be incapable of providing satisfactory difference between short-run and long-run elasticities (McKay *et al.,*1999). In the light of these limitations an alternative to the Nerlovian model is required.

Cointegration methods have the ability to recognise and hence prevent spurious regressions associated with non-stationary series (Engle and Granger, 1987). It also offers the needed mechanism for the utilisation of dynamic error correction models (ECMs) that account explicitly for the dynamic forces of short-run adjustment toward long-run equilibrium.

Drawing on the ability of cointegration analysis to address the issue of spurious regressions, Abdulai and Rieder (1995) applied the method of cointegration and error correction to scrutinise the responsiveness of cocoa farmers to economic inducements. Cointegration was employed to test long-run equilibrium relationships between the series and then offer a basis for the estimation of cocoa supply within an error correction context. Under certain conditions, the dynamic ECM was used in a theoretically consistent manner to model the series by taking account of the dynamics of short-run adjustment towards long-run equilibrium. Similarly, Bulir (1998) uses the ECM in a single-equation manner to model the supply response of cocoa in Ghana, with the error correction term embedded.

Cointegration methods applied to the modelling of supply response are able to provide more general dynamic structures than the Nerlovian models (Soontaranurak and Dawson, 2015). This is because, the essentials of agricultural supply response model which are the partial adjustment in production and the mechanism used by farmers in forming expectations are taken into account in the ECM (Tripathi and Prasad, 2009). Moreover, the significance of the ECM to modelling agricultural supply response is demonstrated by Salmon (1982) and Nickell (1985) who have shown that the ECM can be resultant from the dynamic optimising actions of economic beings.

In studying the techniques used in agricultural supply response studies, Thiele (2000) observes that conducting a co-integration analysis is the most candid means to overcome the limiting dynamic specification of the Nerlovian model since it does not enact any limitataions on the short-run behaviour of prices and quantities. Additionally, ECM is consistent with the forward-looking behaviour of farmers which is an advantage over the partial adjustment mechanism. The ECM also provide a means of adding levels of variables together with their differences and hence of modelling long-run as well as short-run relationships (Hallam and Zanoli, 1993), thereby providing consistent and distinct estimates of long-run and short-run elasticities which is not possible in the case of the typical adaptive expectation and partial adjustment mechanisms as applied in the Nerlovian approach.

Most recent studies on perennial crop supply response (Mustafa *et al.*, 2016; Soontaranurak and Dawson, 2015; Wani *et al.*, 2015) have adopted the vector error correction model (VECM) due to its ability to establishing distinct cointegration vectors and also to appropriately describe data due to its ability to reject additional restrictions imposed by partial adjustment models.

This study adopted the cointegration approach to estimate supply response model for cocoa. The adoption of this approach was due to the unavailability of data regarding new plantings, composition of cocoa trees by age, and annual removals. Such data limitations ruled out the possibility of using the structural equations approach. The direct/Nerlovian approach was overlooked due to the restrictions implicitly imposed and also the spurious results it was likely to provide.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study Area

Ghana is situated on the west coast of Africa with a total area of 238 540 km^2. The country has a north-south extent of about 670 km and a maximum east-west extent of about 560 km. With a population of about 30 million, Ghana shares boarders with Ivory Coast on the west, Burkina Faso to the north, Togo to the east and the Gulf of Guinea and the Atlantic Ocean to the south. The country is divided into 16 administrative regions, of which 10 are cocoa producing.

3.2 Variables Used in the Study

3.2.1 Cocoa Output as the Dependent Variable

Since COCOBOD is the sole buyer of cocoa in Ghana through the CBCs, its annual recorded purchases are a true proxy for the amount of cocoa beans farmers were willing and able to supply at the given time period.

3.2.2 Price of Cocoa

Consistent with economic theory, the price of a commodity is the main determinant of the supply of that commodity. The producer price of cocoa in Ghana determines the profitability of cocoa production which will then influence farmers' decision as to whether to invest in the production of cocoa or otherwise. According to ICCO (2019) cocoa trees take 3-5 years to yield, with hybrid varieties yielding earlier. In this regard the producer price of cocoa was lagged three periods. A lag of three periods was chosen for two reasons, firstly most cocoa farms in Ghana are believed to be composed of hybrids and secondly to conserve degrees of freedom so as to meet statistical requirements. Price was expected to have a positive impact on output supplied.

3.2.3 Price of Maize

Between the period of 2005 to 2014 alone the area under maize cultivation increased by 38% (WB, 2017). As the major staple crop in Ghana, Quarmine *et al*. (2014) regards maize as the crop that competes with cocoa for farmers' limited resources such as labour and land. Maize is also an avenue where farmers choose to invest their limited resources with the aim of recouping their investment in the shortest possible time. The price of maize is a suitable measure of the profitability level of maize production and hence a good measure of farmers’ decision to invest in maize production relative to cocoa. The price of maize was expected to have a negative impact on the supply of cocoa.

3.2.4 Price of Oil Palm

Cocoa farmers have been reported to diversify by growing other perennial crops, particularly as a way to mitigate against all forms of risk associated with cocoa production (Danso-Abbeam *et al.*, 2014). In the course of diversification, farmers make a trade-off between investing their limited resources in cocoa production or oil palm production, this affects the output of cocoa either positively or negatively depending on the choice of the farmer. The profitability of oil palm production determines the share of the limited resources allocated to its production, and this can be captured by the producer price of oil palm in Ghana. This is lagged three periods as it is expected that farmers in deciding to cultivate oil palm compares it to the returns, they would have otherwise received investing in cocoa instead. The price of oil palm was expected to have a negative impact on the supply of cocoa.

As the second most important tree crop in the Ghanaian economy and a leading cash crop in the forest belt of Ghana for most smallholder farmers, Ofosu-Badu and Sarpong (2013) makes the case that world price of palm oil has seen a steady increase from US$350 per MT in the 1990s to a high of US$1 020 per metric tonne in 2011 and estimates that this makes it profitable for Ghanaian farmers engaged in the cultivation of oil palm. Ghana has seen a rapid increase in area under production of oil palm which has resulted in production increasing by 123%, from 850 000 MT in 1990 to 1 900 000 MT in 2012 (Rhebergen *et al*., 2018).

3.2.5 Time Trend

The time trend variable is a proxy for technological change overtime. As indicated by Tomek and Kaiser (2014) continued research results in streams of new technologies entering the market which are assumed to result in an upward trend in yields. Such upward trend in yield translates in the amount of output supplied by farmers. Time trend will serve as a way to accommodate the effects of new technologies arising outside of the government's expenditure on research on the cocoa sub-sector. Overtime technological improvement was expected to have a positive impact on output of cocoa supplied.

3.2.6 Rainfall

The supply of cocoa like all other agricultural commodities is influenced by random states of nature. Ogbu and Gbetibouo (1990) observe that variations in yield can be attributed to variations in weather. To capture the effect of weather in supply response studies rainfall has been used in most of these studies. In line with previous studies, the average annual rainfall is used to capture the effect of weather on the supply of cocoa. The variable is lagged one year as it is expected that the yield in a particular year depends on the weather condition of the previous year. Rainfall was expected to have a positive impact on yield and hence a positive impact on output supplied.

3.2.7 Dummy for Price Difference between Ivory Coast and Ghana Cocoa (PIV)

Dzamboe (2015) noted that, the recent drop in cocoa output could have resulted from cocoa being smuggled out of Ghana, as Ghanaian producer prices fell below those of neighbouring countries. Even though smuggling cannot be observed directly (Bulir, 1998), it can be said to explain supply fluctuations better than most other variables since cocoa can be easily smuggled due to the porous nature of Ghana's borders. To capture the impact of smuggling on the supply of cocoa in Ghana, a dummy variable was used. The dummy took the value of one during periods where the price of cocoa in Ivory Coast was greater than that of Ghana and zero for periods price in Ghana was greater than Ivory Coast. The expected sign was negative since smuggling reduces output offered for sale by farmers to the COCOBOD.

3.2.8 Dummy Variable to Control for Other Government Policies (GOV)

Besides the expenditure government allocates to the cocoa sub-sector annually, the government of Ghana occasionally declares some years as typically for investment in the sub-sector leading to extra expenditure. Such periods are usually followed by booms in the sub-sector due to the extra investment made by the government over the preceding years. The dummy took a value of one for periods of extra government focus and zero otherwise. This dummy variable was lagged one period since it was expected that government policies in a given year will have an impact on cocoa supply in the next harvesting year. The expected sign was positive.

3.2.9 Output Lagged One Period (Qt-1)

Output lagged one period is a proxy for existing capital stock of the farmer (Mamingi, 1997). Since cocoa is a perennial crop and the farmers subsequent output will largely depend on the existing capital stock, it is relevant to include such a variable. Existing capital stock was expected to have a positive impact on output supplied.

3.2.10 Government Expenditure on the Cocoa Sub-sector

Government expenditure on the cocoa sub-sector is disaggregated into expenditure on research and non-research expenditure. A further disaggregation of the non-research expenditure would have been more appropriate but data limitations only allows for these two levels of disaggregation. The effects of agricultural research expenditure tend to materialize with a long-time lag and can persist long afterward (Benin, 2015). In line with existing literature, research expenditure is lagged for three periods so as to accommodate the long-time lag and to conserve degrees of freedom so as to meet statistical requirements. Non-research expenditure is lagged one period since the effects of such spending become visible a year afterwards. The government expenditure on the cocoa sub-sector was expected to have a positive impact on output supplied.

3.3 Analytical Framework

3.3.1 Descriptive Analysis

The history and composition of government expenditure on non-research activities was explained on annual basis. An examination through percentages and averages of the components of non-research expenditure was undertaken, highlighting the various areas that receive the expenditure and in what proportion. A further review of the literature on the cocoa sub-sector was done to point out the non-research activities that such expenditure was allocated for. This was largely descriptive in nature.

3.3.2 Model Specification

Price has been the main variable included in most supply response models. This is mainly because output price increases profit and an increase in profit serves as an incentive for producers or farmers to produce more of the product. However, there are other equally important factors besides output prices that influence agricultural supply (Panagiotou, 2005; Thiele, 2002). Therefore, the model is specified as follows:

$lnCocoaQ_t = \beta_0 + \beta_1 lnCocoaQ_{t-1} + \beta_2 CocoaP_{t-2} + \beta_3 lnMaizeP_{t-1} + \beta_4 lnOilpP_{t-2} + \beta_5 lnResExp_{t-3} + \beta_6 lnNonResExp_{t-2} + \beta_7 TIME_t + \beta_8 RAIN_{t-1} + \delta_1 GOV_{t-1} + \delta_2 PIV_t + \varepsilon_t$ …………………………………………………………………………………. (14)

where;

$lnCocoaQ_t$ = natural log of cocoa output supply

$lnCocoaQ_{t-1}$ = natural log of cocoa output supply in period "t-1" (a proxy for existing capacity)

$lnCocoaP_{t-2}$ = natural log of cocoa price in period "t-2"

$lnMaizeP_{t-1}$ = natural log of maize price in period "t-1"

$lnOilpP_{t-2}$ = natural log of oil palm price in period "t-2"

$\beta_5 lnResExp_{t-3}$ = natural log of research expenditure on cocoa sub-sector in period "t-3"

$lnNonResExp_{t-2}$ = natural log of non-research expenditure on cocoa in period "t-2"

$TIME_t$ = time trend as a proxy for technological improvements over the years

$lnRAIN_{t-1}$ = natural log of annual rainfall as a proxy for weather conditions

GOV_{t-1} = a dummy variable to control for other government interventions in period "t-1"

PIV_t = a dummy to control for the smuggling of cocoa out of Ghana

ε_t – is the error term in the model; β and δ – are the unknown parameters to be estimated

3.3.3 Stationarity and Cointegration of Dataset

The study established the stationarity of the dataset so as to avoid the case of spurious regression results and its associated complications. An assumption was made that the data exhibited white noise in its time series process. Each element in the process was assumed to have a sequence as follows:

$E(\varepsilon_t) = 0$, $E(\varepsilon_t^2) = \sigma^2$ and $Cov(\varepsilon_t, \varepsilon_s)$ for all $t \neq s$ ……………………………………….(15)

An indication that each element in the series was drawn from a population with zero mean, constant variance and independently and identically distributed (Green, 2003). Once the stochastic process was met, the study proceeded to test for unit roots as described by Gujarati (2004) and Green (2012).

The Augmented Dickey-Fuller (ADF) was used to test the stationarity. The test included extra lagged terms of the dependent variable in order to eliminate autocorrelation. The form of ADF adopted for the study wass expressed as:

$\Delta y_t = \alpha_0 + \lambda y_{t-1} + \alpha 2t + \sum_{i=1}^{p} \beta \Delta y_{t-i} + \upsilon_t$ ……………………………………………. (16)

This equation for testing unit roots comprised of an intercept and a trend to help explain the variable of interest.

After establishing stationarity in the dataset, the study then proceeded to test for cointegration between the variables. The presence of cointegration implied that there existed a meaningful relationship between the variables. The Johansen Procedure for cointegration is based on a likelihood statistic, with the null hypothesis of no cointegration. The procedure tests the hypothesis of no cointegration vectors (r = 0). The existence of a cointegrating relation then formed the basis of the vector error correction model specification.

3.3.4 Estimation Procedure

In accordance with the existing literature on perennial crop supply response studies, the vector error correction model was adopted for this study. A vector error correction model is a restricted vector autoregression intended for use with nonstationary series that are known to be cointegrated. The cointegrating term is the error correction term since the deviation from the long-run equilibrium is corrected progressively via a series of partial short-run adjustments. The VECM is presented as:

$$\Delta lnCocoaQ_t = \theta_0 + \theta_1 \Delta lnCocoaQ_{t-1} + \theta_2 \Delta lnCocoaP_{t-2} + \theta_3 \Delta lnMaizeP_{t-1} + \theta_4 \Delta lnOilpP_{t-2} + \theta_5 \Delta lnResExp_{t-3} + \theta_6 \Delta lnNonResExp_{t-2} + \theta_7 \Delta TIME_t + \theta_8 \Delta lnRAIN_{t-1} + \delta_1 GOV_{t-1} + \delta_2 PIV + \lambda ECT_{t-1} + \varepsilon_t \quad (17)$$

Note: ECT is the error correction term, that is, the long-run supply response function.

$$ECT_{t-1} = lnCocoaQ_t - \beta_0 - \beta_1 lnCocoaQ_{t-1} - \beta_2 lnCocoaP_{t-2} - \beta_3 lnMaizeP_{t-1} - \beta_4 lnOilpP_{t-2} - \beta_5 lnResExp_{t-3} - \beta_6 lnNonResExp_{t-1} - \beta_7 TIME_t - \beta_8 lnRAIN_{t-1} - \Psi_1 GOV_{t-1} - \Psi_2 PIV_t \quad (18)$$

Where:

Δ is the difference operator

λ measures the speed of adjustment

$\theta_0, \theta_1, \theta_2, \theta_3, \theta_4, \theta_5, \theta_6, \theta_7, \theta_8, \delta_1$ and δ_2 are short-run elasticities to be estimated

$\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7, \beta_8, \Psi_1$ and Ψ_2 are long-run elasticities to be estimated.

3.4 Sources and Description of Data

Data on the quantity of cocoa supplied was estimated by the annual quantity of cocoa purchased obtained from COCOBOD's website. This amount represents the quantity of cocoa farmers are willing and able to supply in a given year at the existing price level.

Prices received by Ghanaian cocoa farmers are determined by the Producer Price Review Committee and announced in the annual budget of Ghana. Data on the price of cocoa per MT from the year 1996/97 to 2013/14 was obtained from the Cocoa Sector Expenditure and Revenue in Ghana dataset, prices for 2014/15 and 2015/16 harvest season were obtained from the annual budget of 2013 and 2014 respectively. Using the prices from the annual budget was necessitated due to the inability of the dataset to capture the prices during the said years. The prices from the annual budget are accurate representation of the producer prices for the given years since cocoa prices are determined by the government and announced yearly through the budget.

Data on expenditure on the cocoa sub-sector was obtained from the Cocoa Sector Expenditure and Revenue in Ghana dataset. The dataset aggregates information from various sources including Food and Agriculture Organization (FAO), Ghana Cocoa Board (COCOBOD), and Producer Price Review Committee (PPRC). These data are available for the 1996/97 harvest season to that of 2012/13. By fitting and plotting the existing data, a linear equation was obtained to extrapolate values for the 2013/14, 2014/15 and 2015/16 harvest seasons. The data disaggregates the annual expenditures into those spent on research and those on non-research activities.

Data on oil palm and maize prices per metric tonne were obtained from FAOSTAT ranging from the 1996/97 to 2011/12 harvest seasons. A linear function of the second order was used to extrapolate the price of oil palm from 2012/13 to 2015/16 harvest seasons. Another linear function was used to extrapolate maize prices from the 2012/13 to 2015/16 harvest seasons. Beginning from the 1996/97 harvest season, a value of one is used for the time trend variable and ends with the 2015/16 season at 20.

The dummy variable controlling for other government policies takes the value of zero 1996/97 to 1999/00 harvest season. This was a part of period from 1991 to 1999 when there was a complete pull-out of the direct government involvement in production and stoppage of subsidies. The variable takes a value of one from 2000/01 to 2015/16, this captures the period of CAADP and the reintroduction of subsidies.

Data on annual rainfall was obtained from the climate knowledge portal of the World Bank. Monthly rainfall data was obtained and then average annual rainfall was calculated from such data.

The dummy variable for smuggling was based on price difference between Ghanaian and Ivorian cocoa farmers. Given that a government subsidiary is the sole buyer of cocoa beans in Ghana at the same price, farmers are likely to be tempted seek higher producer prices from neighbouring countries. However, for farmers to take such a risk, the price difference will have to be very significant such that it can cover all cost involved and results in profit. Based on cocoa price per tonne in US$ for both countries from FAOSTAT, it is estimated that a cocoa farmer in Ghana will opt to smuggle and sell his/her cocoa beans in Ivory Coast if there is a difference of US$50 (GHS250). The dummy takes the value of one if price per metric tonne in Ivory Coast is US$50 more than the price received by farmers in Ghana and zero if otherwise.

Data on all expenditures and prices have been adjusted for inflation using 2017 as the base year. The overall CPI for 2017 was used to deflate the nominal expenditure and price values obtained from the original sources. The CPI was obtained from the Bank of Ghana website.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 General Description of Variables

An examination of the values of the variables using a trendline indicates that with the exception of average annual rainfall, all the other variables showed an upward trend, this is despite the occational fluctuations withnessed. A general picture reveals that cocoa output and prices, prices of maize and oil palm as well as government expenditure on research and non-research activities all tend to move upward. Rainfall which is a proxy for weather however shows a downward trend implying that there is a deteriorating weather condition.

As indicated in Fig. 2 for the 20-year period under consideration, the mean annual cocoa ouput recorded was 632 808.6 MT per year. The 1996/97 season recorded the lowest output level of 322 489 MT, while the 2010/11 season recorded the highest output level of 1 012 839 MT.

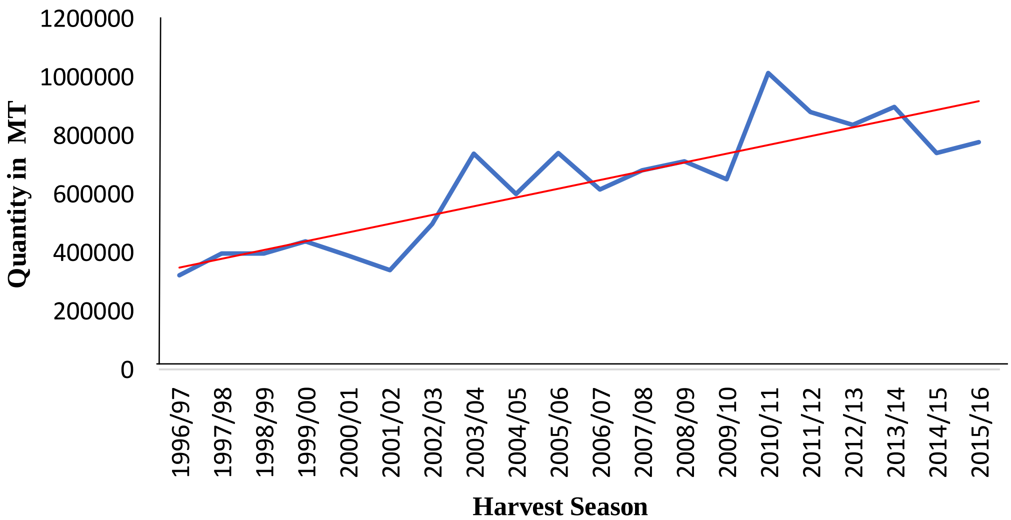

Figure 2: Trend of cocoa output in Ghana

As depicted in Fig. 3, real price of cocoa has shown a rise from a low of GHS 745.6 per MT in the 1996/97 season to a high of GHS 8 669.9 per MT in the 2015/16 season. The average real price over the 20-year period has been GHS 2 197.7 per MT. However, real producer price of cocoa in Ghana witnessed a sharp rise from the 2012/13 harvest season until the 2014/15 harvest season before normalising in the 2015/16 harvest season.

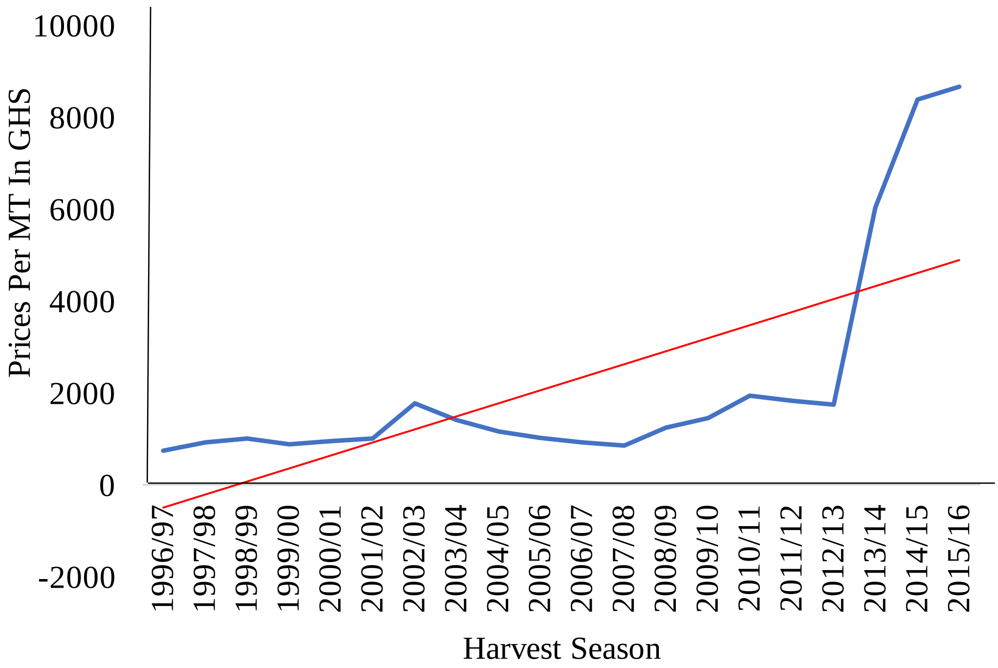

Figure 3: Real cocoa price levels

Fig. 4 shows that research expenditure on the cocoa sub-sector has witnessed significant increases during the period. For the 17 years of data available, expenditure on research recorded its lowest allocation of GHS 4 022 438.5 during the 1996/97 season to a high of GHS 26 502 497.8 during the 2011/12 season. The average real expenditure on research activities over the 17-year period has been GHS 11 373 869.4. Although research expenditure has seen a steady rise, the level of expenditure declined sharply in the 2012/13 harvest season.

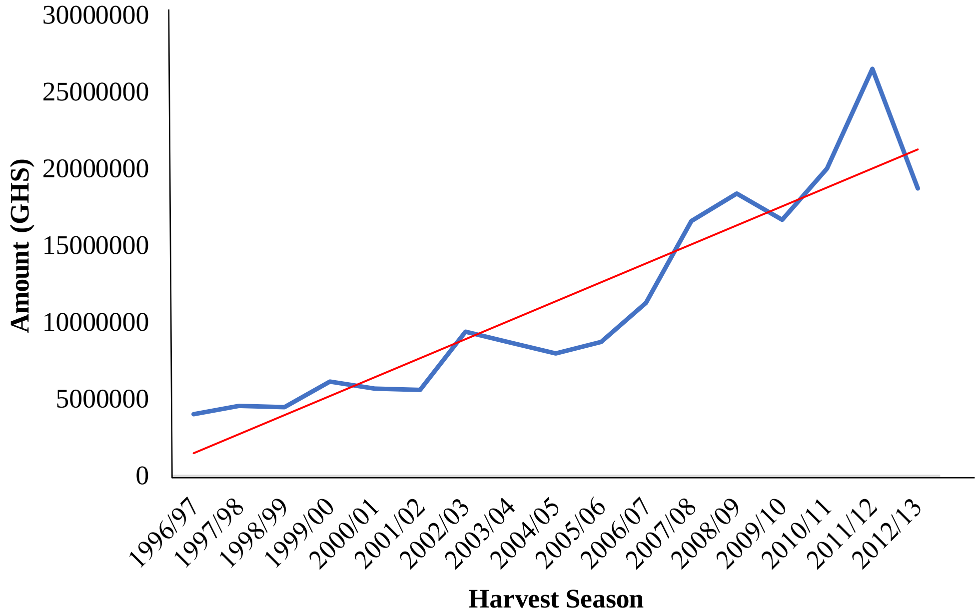

Figure 4: Real research expenditure levels

As indicated in Fig. 5, the average real expenditure on non-research activities over the period has been GHS 107 914 579.6. Real expenditure over the period has had a low of GHS 48 468 584.9 in the 1998/99 season to a high of GHS 267 793 083.3 during the 1999/00 season. Non-research expenditure for the 1999/00 harvest season stands out since there was a sharp rise from the 1998/99 harvest season and after 1999/00 harvest season witnessed another sharp decline to a low amount in the 2000/01 harvest season.

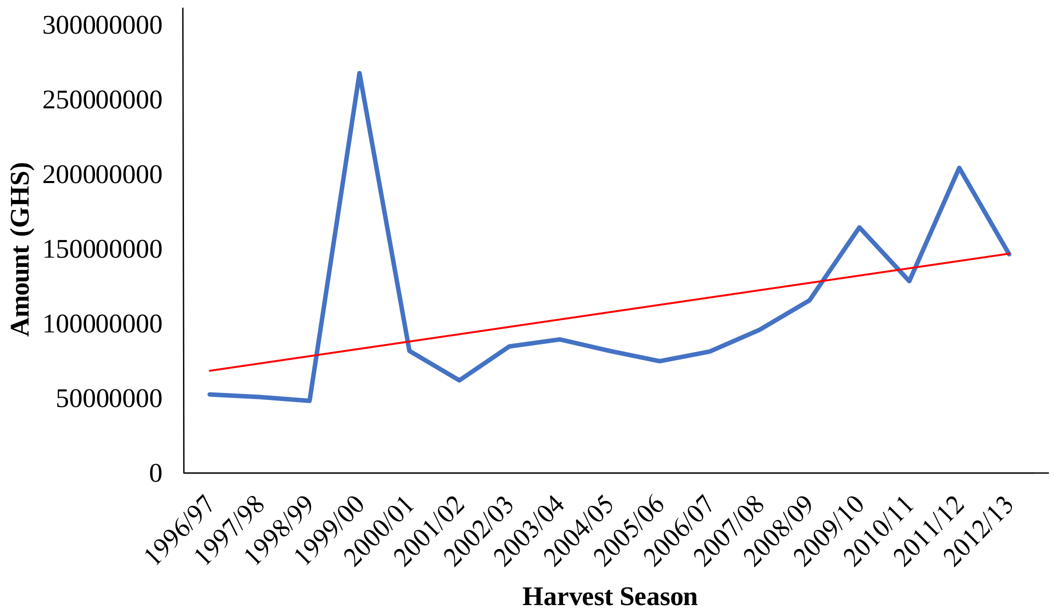

Figure 5: Real non-research expenditure levels

The average rainfall recorded during the period under consideration is 1161.2 millimetres (mm), the 1998/99 season recorded the lowest rainfall of 989.8mm, with the 2008/09 season recording the highest rainfall of 1326.7mm. For the 16 years of available data on maize price, the average real price of maize per MT was GHS 286. The 1999/00 season recorded the lowest real price of GHS 178 per MT, with the highest real price being GHS 375 per MT during the 2005/06 season.

For the 16 years available data on oil palm prices, an average real price of GHS 112 per MT is recorded. Real price of oil palm over the period has risen from a low of GHS 40.4 per MT in the 1996/97 season to a high of GHS 145.2 during the 2001/02 season.

Imposing a trend line in Fig. 6 indicates a general decline in growth of cocoa output overtime. The highest growth experienced was during the 2010/11 season when output recorded a growth of 56 %. The 2004/2005 season witnessed the largest decline with a negative rate of 19 %. Another important observation is the decline of 18 % in output during the 2014/15 harvest season. The decline witnessed in 2014/15 season despite a sharp increase in real producer price during the same period sheds light on the lagged effect producer prices has on cocoa output. The decline can be attributed to the declining rate of change in real prices experienced in the previous three harvest seasons which may have disincentivise farmers from allocating more resources to cocoa production.

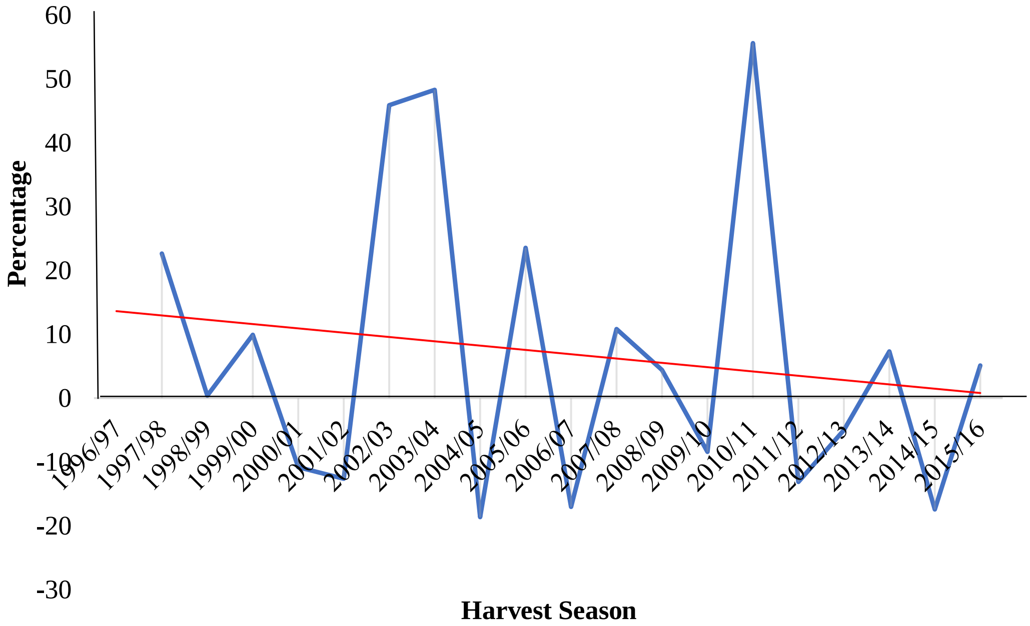

Figure 6: Rate of change in cocoa output

As indicated in Fig. 7, the growth in real price of cocoa in general has been on the upward. This is despite the fact of experiencing the largest decline of 20 % during the 2003/04 season. The largest growth in the real price of cocoa was 247 % recorded during the 2013/14 season.

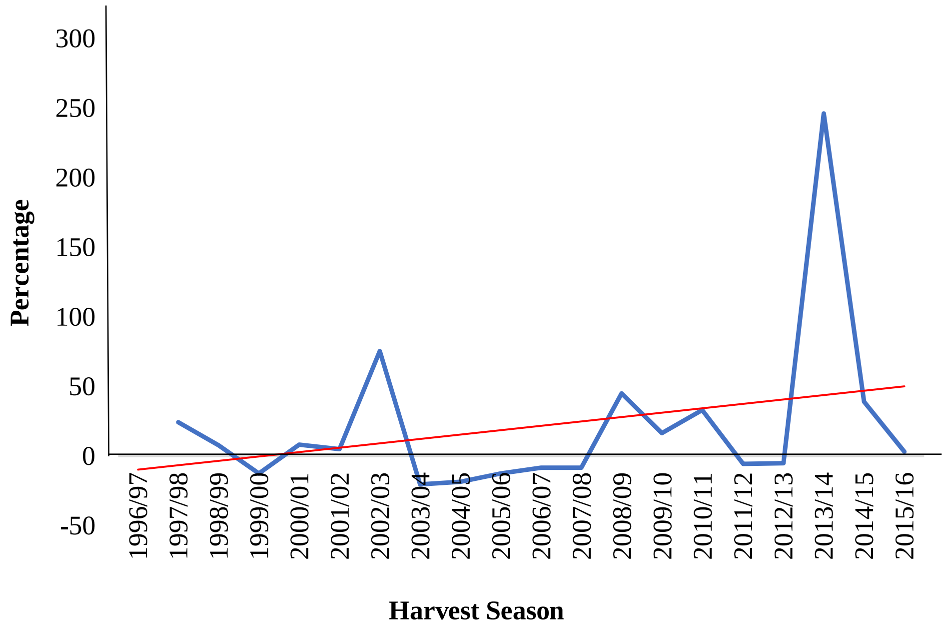

Figure 7: Changes in real price of cocoa

As shown in Fig. 8, cocoa research expenditure recorded its largest growth of 68 % during the 2002/03 harvest season. The growth in such expenditure has not been stable over the years recording its highest decline of 29 % during the 2012/13 season. A trend line shows that the rate of growth in real research expenditure is on the decline.

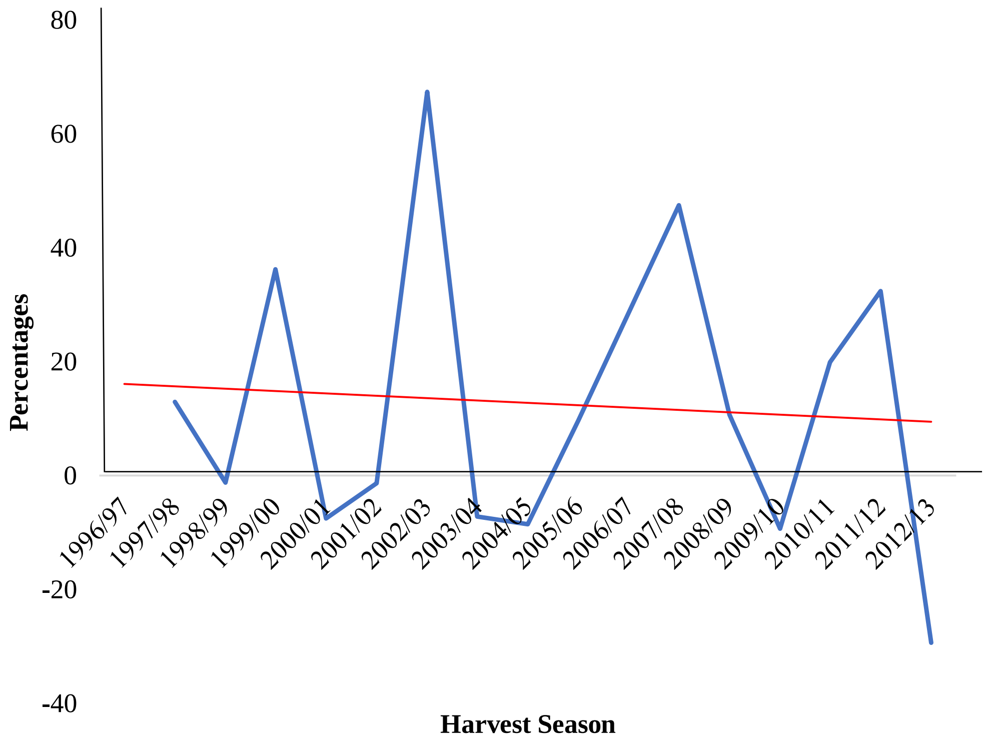

Figure 8: Changes in real research expenditure on cocoa

As observed in Fig. 9, the highest percentage change in government expenditure on non-research activities was 453 % during the 1999/00 harvest season. This trend took a sharp decline of 69 % in the 2000/01 harvest season. A trend line indicates a declining movement in the growth of government's non-research expenditure.

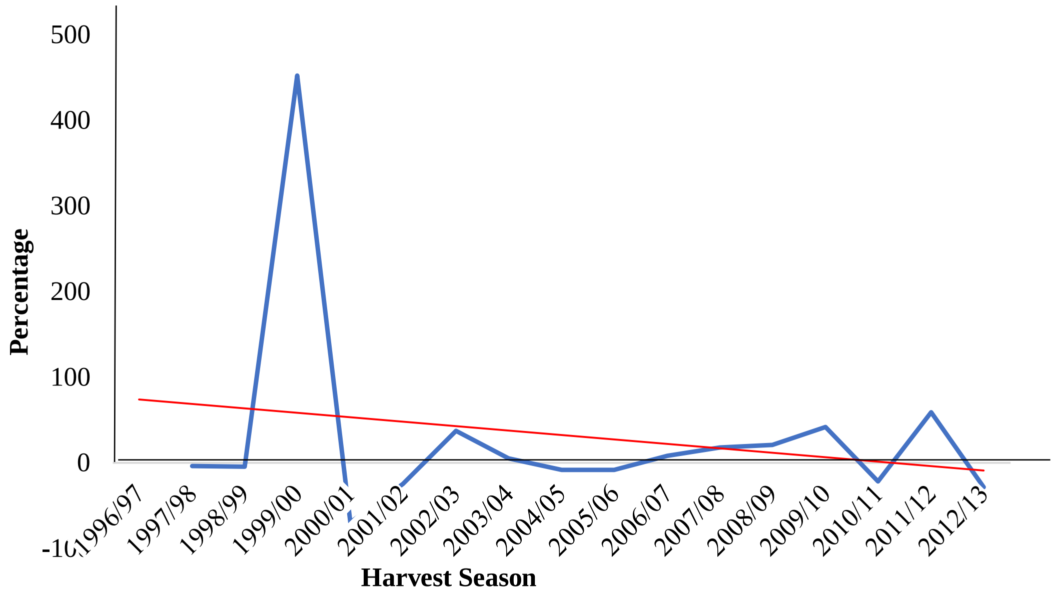

Figure 9: Changes in real non-research expenditure on cocoa

A look at the general growth rate in both the real price of maize and oil palm overtime shows a downward trend. The highest growth rate recorded for real prices of maize was in the 1997/98 season with a 68 % increase in real price. However, 2002/03 season saw a decline of 24 % in real price, the highest decline over the period. Changes in the real price of oil palm has been relatively lower. The highest change in real price of oil palm was recorded in the 1997/98 season when real price increased by 182 %. The 2000/01 season witnessed a decline of 12 % in real price of oil palm which happens to be the largest decline over the period under study.

As observed in Fig. 10, real research expenditure and cocoa output expresses a mirror imaging pattern, with both rising steadily from the period 1996/97 until 1999/00 season. This period also shows a declining trend in the real non-research expenditure but a sharp increase in 1999/00 season followed by a sharp decline in 2000/01 season. The mirroring image pattern between cocoa output and real research expenditure continues, but this time in a fluctuating manner. The relationship between real non-research expenditure and cocoa output is not one of a clear nature. Real non-research expenditure shows fluctuations that cannot be logically related to fluctuations in cocoa output.

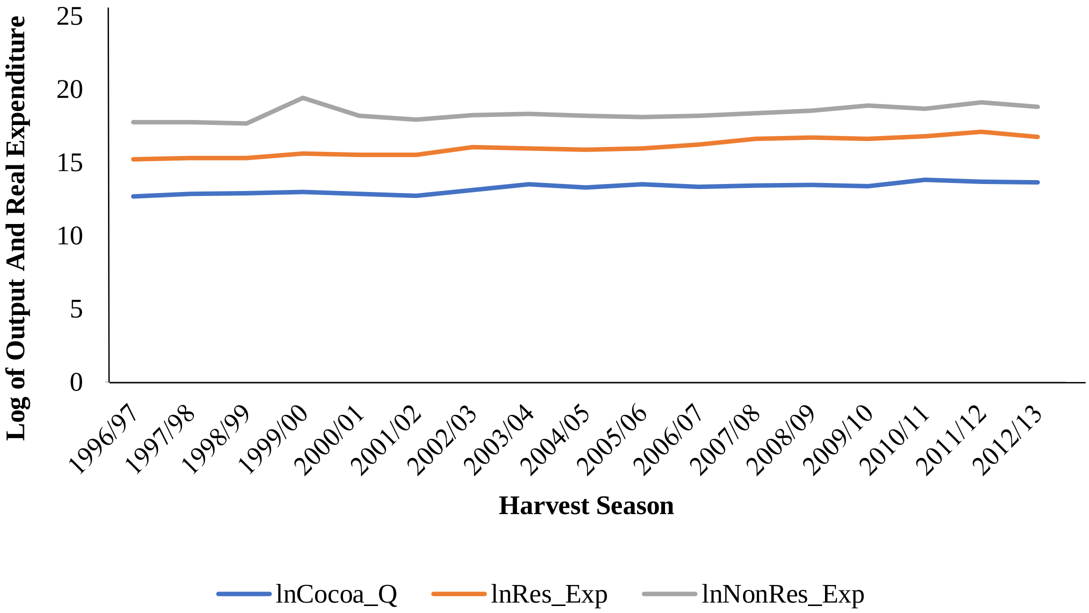

Figure 10: Comparison of cocoa output, real research expenditure and non-research expenditure

4.2 Composition and Pattern of Non-research Expenditure on Cocoa sub-sector

Expenditure for non-research activities comprises of allocations to several units within COCOBOD. The data shows that allocations for non-research activities include those made to Cocoa Swollen Shoot Virus Disease Control Unit (CSSVD), Seed Production Unit (SPU), Cocoa Service Division (CSD), Bonsu Cocoa College (BCC) and the Head Office (H-O) as well as allocation for capital expenditure (K-Exp).

Expenditure of the CSSVD is for the regulation of the swollen shoot disease which affects cocoa farmers' production capabilities. Given the task of SPU, their expenditure is for the production and distribution of hybrid cocoa seed pods and seedlings to cocoa farmers.

The expenditure of CSD is basically for extension services to cocoa farmers. The Bonsu Cocoa College is tasked with the training of technical and field staff of COCOBOD. Expenditure of the head office is largely for administrative purposes all geared towards improving cocoa output. The capital expenditures are those for the acquisition, enhancement, or upkeep of long-term resources to improve the efficiency or capacity.

A look at the real expenditure on non-research activities in Fig. 11 indicates that a large share of such expenditure is allocated to the head office for administrative duties. The 1999/00 season recorded the highest real allocation of GHS 267 793 087, with the lowest allocation recorded in the 1996/97 season for administrative purposes. Data on expenditure for extension services is available for only the 1996/97 and 1997/98 seasons. Real expenditure for the control of swollen shoot disease recorded its highest value in the 2011/12 season with a value of GHS 57 100 903 and lowest expenditure of GHS 10 544 459 during the 2001/02 season. Real expenditure for the production and distribution of hybrid seedling recorded its highest value of GHS 15 862 384 during the 2012/13 season and the lowest real expenditure of GHS 2 518 537 during the 2000/01 season. With regards to the real expenditure for the training of technical and field staff, the highest expenditure of the BCC was recorded in the 2003/04 season with a value of GHS 7 739 705 and the lowest allocation of GHS 143 100 during the 2003/04 season. Real capital expenditure has been on the rise over the years, the highest real capital expenditure of GHS 67 817 621 was recorded in the 2011/12 season with the lowest expenditure recorded being GHS 2 027 702 in the 2000/01 season.

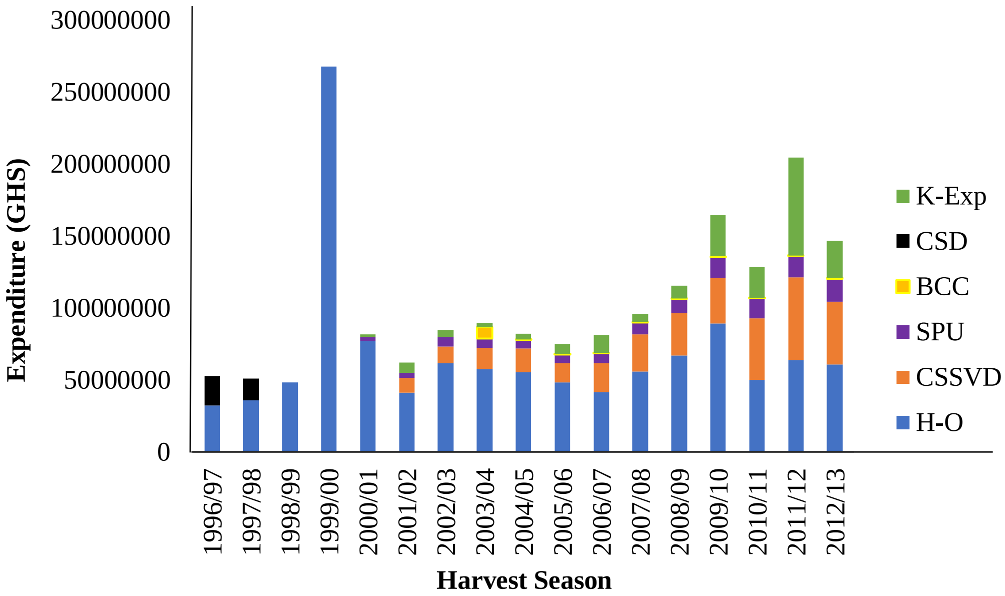

Figure 11: Composition of real Non-research expenditure

As a percentage of overall annual non-research expenditure in Fig. 12, expenditure of the head office continues to have the largest portions yearly. With as large as 100 % in 1998/99 and 1999/00 seasons to a minimum portion of 31 % in 2011/12 season. The fight against swollen shoot disease has resulted in expenditure of the CSSVD range from as large as 33 % to a low of 14 % of total non-research expenditure in the 2010/11 and 2002/03 seasons respectively. Expenditure of SPU as a percentage of overall non-research expenditure ranges from a high of 11 % in 2010/11 season to a low of 3 % in 2000/01 season. The share of capital expenditure has witnessed immense growth over the period. Beginning at a low of 3 % in 2000/01, capital expenditure as a percentage of overall non-research expenditure reached a maximum of 33 % in the 2011/12 season. Expenditure of the BCC for the training of technical and field staff as a percentage of overall non-research expenditure has not been much compared to the others. The largest share as a part of overall non-research expenditure was 9 % during 2003/04 season and the lowest percentage of 0.17 % recorded for the 2004/05 season. For the two years of available data on expenditure on extension services, the percentage share was 39 % and 29 % for the 1996/97 and 1997/97 seasons respectively.

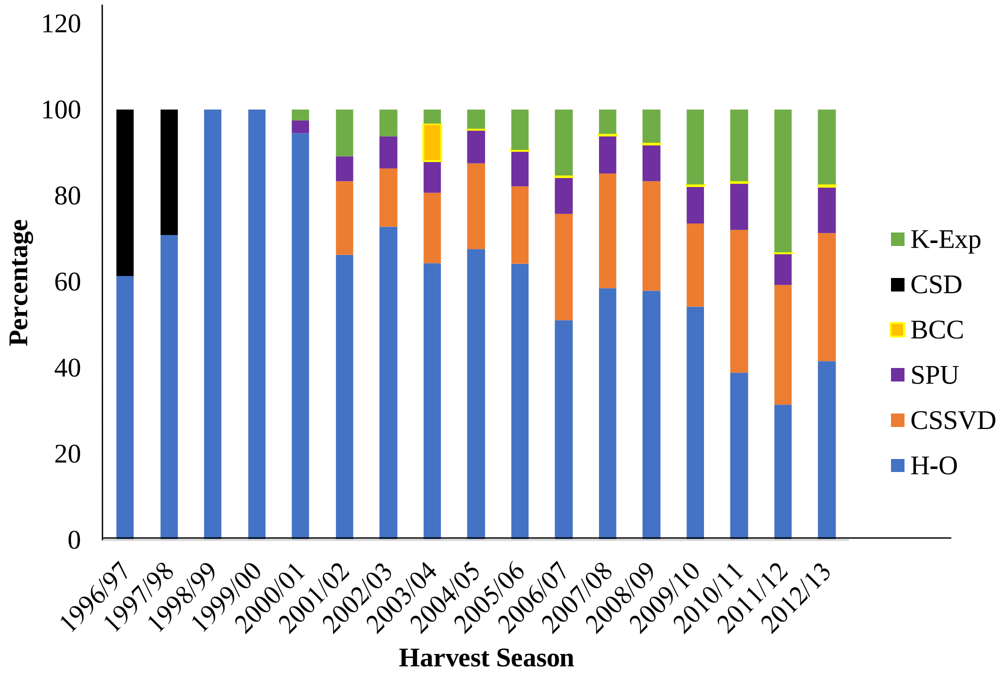

Figure 12: Composition of real Non-research expenditure in percentages

As observed in Fig. 13, over the period under consideration, on average 50 % of all non-research expenditure is allocated to the head office of COCOBOD which is largely for administrative purposes. The expenditure of CSSVD forms the second largest component of 19 %. The CSD which is in charge of extension services has the third largest average expenditure of 13 %. Capital expenditure on average accounts for 11 % of non-research expenditure followed by expenditure of SPU in fifth place with an average of 6 % of overall expenditure. The BCC received the least average component of expenditure of 1 %.

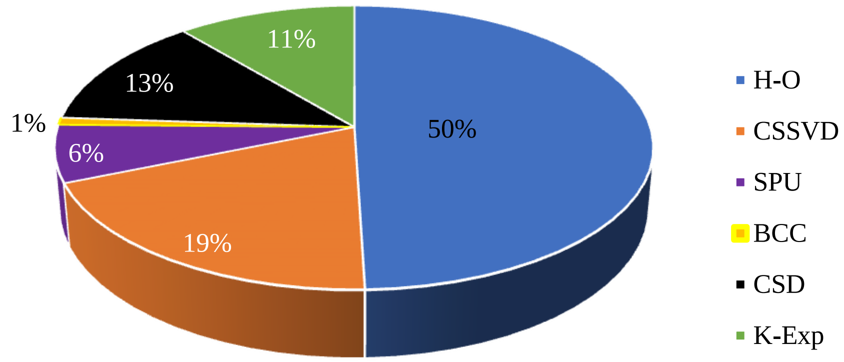

Figure 13: Pattern of real non-research expenditure allocation

4.3 Estimation of the Supply Response Model

4.3.1 The Augmented Dickey–Fuller (ADF) Test for Unit Roots

The ADF statistic was used to test for the presence of unit roots. The results presented indicate that all variables are non-stationary without taking the first difference. Differencing ensured that all the variables achieve stationarity. The null hypotheses of a unit root (non-stationarity) is rejected in favour of the alternative of no unit root (stationarity) if the ADF statistic is greater in absolute terms than the MacKinnon critical value.

Table 1: ADF Test for Unit Roots Results

Variable	ADF Statistic	Lag Length	Critical Value	P-Value
D (CocoaQ)	-6.258832	1	-4.571559 ***	0.0004
D (RAIN)	-6.949489	1	-4.571559 ***	0.0001
D (CocoaP)	-3.579678	1	-3.297799 *	0.0626
D (MaizeP)	-4.333726	1	-3710482 **	0.0166
D (NonResExp)	-4.006327	1	-3.710482 **	0.0298
D (oilpP)	-3.732117	1	-3.297799 *	0.0482
D (ResExp)	-4.431985	1	-3.710482 **	0.0139

MacKinnon critical values for rejection of hypothesis of unit root at *** = 1%, ** = 5% and * = 10% significance level.

The results (Table 1) indicate that all the variables became stationary after first differencing with a constant and a trend term since the ADF statistic is larger than the MacKinnon critical values in absolute terms. By implication, all the variables are integrated of order one [I(1)].

4.3.2 Optimal Lag Selection

Before a cointegration test and hence a VEC modelling could proceed there was the need to select an optimal lag order to be used for the test for cointegration.

Table 2: The results for the VAR Lag Order Selection Criteria

Lag	LogL	SC	HQ
0	-1360.985	144.3463	144.0573
1	-1279.993	143.4144*	141.1019*

*indicates lag order selected by the criterion

SC: Schwarz information criterion and HQ: Hannan-Quinn information criterion.

By using both the Schwarz information criterion and Hannan-Quinn information criterion, a lag order of one is selected to be used in the test for cointegration.

4.3.3 Test for Cointegration

The test for cointegration between variables is a prerequisite to using the VECM. The presence of cointegration implies there exist a long-run equilibrium between the variables of interest. Green (2012) points out that, a necessary condition before running a VECM is that the variables are cointegrated at the same level.

Table 3: Johansen Cointegration Test

Hypothesis	Trace statistic	Max-Eigen statistic	Critical values (5%) Trace	Max-Eigen
r = 0	119.0608 **	69.01302 **	69.81889	33.87687

** denotes significance at 5% significance level

The null hypothesis being tested is that: there is no cointegration between the series. This hypothesis is rejected at the 5 percent significance level based on both the Trace and Maximum-Eigen statistics. In effect there exist a long-run equilibrium relationship between the five series that were tested. The test indicates that there is a long-run relationship between cocoa output, real price of cocoa, real price of maize, real research expenditure and real non-research expenditure. The other two variables, average rainfall and real price of oil palm were eliminated from the test due the problem of autocorrelation.

4.3.4 Estimation of the Vector Error Correction Model

Based on theory, eleven variables were used in the specification of the supply response model. These variables were, cocoa output, cocoa output lagged, cocoa prices, maize prices, oil palm prices, rainfall, time trend, two dummy variables (PIV and GOV), research expenditure and non-research expenditure. In the estimation process however, four of these variables (oil palm prices, rainfall, PIV and GOV) were rejected due to problems of serial correlation. Due to the rejection of these variables, the study proceeds with the variables that were accepted for the estimation as shown on (Table 4).

Table 4: **Vector Error Correction Model Results**

Variables	**Coefficients**	**Standard Errors**	**T-Statistics**	**P-values**
Long-Run Estimates				
lnCocoaQ(-1)	1.0000			
lnResExp(-1)	1.075274	0.06789	15.8381***	
lnNonResExp(-1)	0.068550	0.03357	2.04229**	
Trend	-0.188502	0.00767	-24.5818***	
C	-29.87838			
Short-Run Estimates				
CointEq1	-0.977378	0.29245	-3.34208	0.0156**
∆lnCocoaQ(-1)	-0.217185	0.26662	-0.81460	0.4464
∆lnCocoaQ(-2)	-0.037015	0.20066	-0.18447	0.8597
∆lnResExp(-1)	1.086577	0.26406	4.11484	0.0063***
∆lnResExp(-2)	0.985320	0.28776	3.42415	0.0141**
∆lnNonResExp(-1)	-0.183387	0.06357	-2.88485	0.0279**
∆lnNonResExp(-2)	-0.100597	0.08309	-1.21066	0.2715
∆lnCocoaP	0.311581	0.10023	3.10859	0.0209**
∆lnMaizeP	-0.465505	0.13014	-3.57690	0.0117**
C	0.282092	0.45616	0.61841	0.5590
R-squared	0.870547	F-statistic	4.483208	
Adj. R-squared	0.676368	Prob(F-statistic)	0.040823	
		Durbin-Watson	1.673752	

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

Based on estimates above the supply response function for cocoa in Ghana was written as:

$$\Delta lnCocoaQ_t = -0.977378\{1.0000 lnCocoaQ_{t-1} + 1.075274 lnResExp_{t-3} + 0.068550 lnNonResExp_{t-2} - 0.188502 Trend - 29.87838\} - 0.217185 \Delta lnCocoaQ_{t-1} - 0.037015 \Delta lnCocoaQ_{t-2} + 1.086577 \Delta lnResExp_{t-3} + 0.985320 \Delta lnResExp_{t-4} - 0.183387 \Delta lnNonResExp_{t-2} - 0.100597 \Delta lnNonResExp_{t-3} + 0.311581 \Delta lnCocoaP_{t-2} - 0.465505 \Delta lnMaizeP_{t-1} + 0.282092$$

An R-squared of 0.870547 indicates that, 87.1 % of variations in cocoa supply can be explained by the variables in the model. With an F-Statistic probability of 0.040821 we can conclude that the model as a whole is statistically significant at 0.05 significance level.

4.3.5 Interpretation of Short-run Elasticities

Based on the results (Table 4) a short-run supply equation for cocoa in Ghana was given as:

$$\Delta lnCocoaQ_t = -0.977378ECT_{t-1} - 0.217185\Delta lnCocoaQ_{t-1} - 0.037015\Delta lnCocoaQ_{t-2} + 1.086577\Delta lnResExp_{t-3} + 0.985320\Delta lnResExp_{t-4} - 0.183387\Delta lnNonResExp_{t-2} - 0.100597\Delta lnNonResExp_{t-3} + 0.311581\Delta lnCocoaP_{t-2} - 0.465505\Delta lnMaizeP_{t-1} + 0.282092$$

The coefficient of the ECT measures the speed of adjustment. The -0.977378 indicates that about 97.74 % departure from long-run equilibrium is corrected in each period. In other words, the previous period's deviation from long-run equilibrium is corrected in the current period at an adjustment speed of 97.74 %. Economically, any short-run deviation will take a little over a year to adjust to long-run equilibrium, an indication of fast adjustment. Given a p-value of 0.0156 which is less than our 0.05 significance level, it indicates that the speed of adjustment is highly significant at 5 %.

The lagged values of cocoa output as variables are proxies for existing capacity of the cocoa farmer. Contrary to our a priori expectation, cocoa output lagged for one and two periods both had negative effects on current cocoa output supplied. In the short-run, a percentage increase in existing capacity of the previous year is estimated to cause an average decline of 0.22 % in current cocoa output supply holding all other factors constant. It is also estimated that if the existing capacity of the farmer two periods before increases by 1 %, the mean cocoa supply will decrease by 0.04 % all other things being equal. These two variables however, were found not to be statistically significant at any of the significance levels as their p-values of 0.4465 and 0.8598 are greater than the 0.01, 0.05 and 0.1 significance levels.

In the short-run, research expenditure on cocoa is captured in two variables $ResExp_{t-3}$ and $ResExp_{t-4}$ with their short-run elasticities being 1.0866 and 0.9852 respectively. As expected, research expenditure has positive effect on cocoa output supply. In the short-run it is estimated that if research expenditure in period t-3 increases by 1 %, the mean cocoa supply will increase by 1.0866 % holding all other variables constant. It is estimated that in the short-run if research expenditure in period t-4 increases by 1 %, the mean cocoa supply will increase by 0.9852 % holding all other variables constant. Based on the p-values, $ResExp_{t-3}$ and $ResExp_{t-4}$ are statistically significant at 0.01 and 0.05 significance levels respectively, the results are consistent with the findings of Fan *et al.*, (2003).

The Cocoa Research Institute of Ghana which is in charge of research pertaining to cocoa production have been able to ensure short-term benefits to farmers under their crop and practice innovations. With regards to crop innovations, the development of early-bearing, high-yielding and disease-resistant varieties are geared towards the realisation of benefits by cocoa farmers in the short-term. Practice innovations resulting from research have been largely in terms of the short-term control of black pod disease instead of the old practice of cutting down the cocoa trees. Such innovations have made it possible for cocoa farmers to enjoy short-term benefits arising from cocoa research activities. These empirical results confirm the theory that research expenditure increases productivity hence leading to increased output levels.

Short-run elasticities for non-research expenditure is captured by two variables $NonResExp_{t-2}$ and $NonResExp_{t-3}$. Contrary to our expectations, non-research expenditure had a negative effect on cocoa supply in the short-run. supply. In the short-run it is estimated that if non-research expenditure in period t-2 increases by 1 %, the mean cocoa supply will decrease by 0.1834 % holding all other variables constant. It is estimated that in the short-run if non-research expenditure in period t-3 increases by 1 %, the mean cocoa supply will decrease by 0.1006 % holding all other variables constant. Based on the p-values, $NonResExp_{t-2}$ is statistically significant at 0.05 significance level while $NonResExp_{t-3}$ is statistically insignificant at all the significance levels. This empirical result is contrary to the theory that government agricultural expenditure increases output although the result is consistent with the findings of Matthew and Mordecai (2016) in their study of Nigeria. The contradiction from theory can be explained by the possible wrong targeting of such non-research expenditure. As indicated by the disaggregation of non-research expenditure, 50 % of all non-research expenditure have been mainly for administrative purposes. This leaves the other equally non-research activities such as disease control, extension services, staff training and subsidised inputs to be woefully catered for in terms of expenditure allocation. Even though such administrative expenditure ensures the smooth execution of various services, denying such other services the right portion of expenditure tend to have a negative impact.

As stipulated in price theory, the own price elasticity of cocoa is positive showing a positive relationship between price and output supplied. In the short-run it is estimated that if cocoa price in period t-2 increases by 1 %, the mean cocoa supply will increase by 0.3116 % holding all other variables constant. Operating on the assumption that cocoa farmers allocate their resources, that is, variable inputs to either maintaining their existing cocoa farm or cultivating other crops, an increase in the price in the previous two years will cause farmers to switch more resource into cocoa farming hence a delayed but subsequent increase in the output of cocoa supplied. By implication, changes in cocoa prices will cause short-term responses from output of cocoa supplied since farmers may decide to increase supply by better management of existing cocoa farms or otherwise. The result is statistically significant at 0.05 level of significance since its p-value of 0.0209 is less than the 0.05 level of significance and is consistent with the findings of (Ankrah, 2014; Wani *et al.,* 2015).

As stipulated in theory, the price of alternatives have a negative effect on the output supplied, this explains the negative relationship between the price of maize and output of cocoa supply. In the short-run it is estimated that if maize price in period t-1 increases by 1 %, the mean cocoa supply will decrease by 0.4655 % holding all other variables constant. This result indicates that, favourable maize prices will cause farmers to shift resources from cocoa production into maize production so as to maximise benefits. The result is statistically significant at 0.05 level of significance since its p-value of 0.0117 is less than the 0.05 level of significance and is consistent with the findings of (Wani *et al.,* 2015).

4.3.6 Interpretation of Long-Run Elasticities

Contrary to our expectation, the results revealed that cocoa prices and the price of maize had no long-run effects on the level of cocoa supply. This may be due to the perennial nature of cocoa; cultivation of cocoa is a long-term investment whose benefits are spread over a twenty-five-year period when the cocoa trees stop being productive. Once planted a cocoa farmer will only commit resources to maintaining the coca farm depending on the short-run price changes which will be beneficial in the short-run. In the long-run however, prices will not be effective in influencing the level of cocoa beans supplied since farmers are not assured of favourable prices in the long-run.

The cointegrating equation (long-run model) was given as:

$lnCocoaQ_{t-1} = 1.075274lnResExp_{t-3} + 0.068550lnNonResExp_{t-2} - 0.188502Trend - 29.87838$

In the long-run, research expenditure on cocoa is captured by the variable $ResExp_{t-3}$ which provided the long-run elasticity of 1.0753. As expected, research expenditure has positive effect on cocoa output supply. In the long-run it is estimated that if research expenditure in period t-3 increases by 1 %, the mean cocoa supply will increase by 1.0753 % holding all other variables constant. With a calculated t-statistic of 15.8381, we can conclude that research expenditure in period t-3 is statistically significant at 0.01 significance levels. The empirical result confirms the theory that research expenditure increases productivity hence leading to increased output levels and the result is similar to findings by (Mohan *et al.*, 1010).

Non-research expenditure in the long-run proved to have a positive effect on cocoa supply. In the long-run it is estimated that if non-research expenditure in period t-2 increases by 1 %, the mean cocoa supply will increase by 0.0686 % holding all other variables constant. With a calculated t-statistic of 2.528, we can conclude that non-research expenditure in period t-2 is statistically significant at 0.05 significance levels. Even though this change is marginal it supports the theory that government expenditure increases output. The positive effect of non-research expenditure in the long-run is a sharp contrast to the negative impact it has in the short-run. It can be argued that the smaller shares of non-research allocations to extension and disease prevention services accumulates in the long-run and in effect produces a positive impact on output eventually a result consistent to findings by (Wangusi and Muturi, 2015).

A trend variable was added to account for all other technological advances in cocoa production that does not arise from government expenditure. The a priori expectation was that such technological advances will have a positive effect on cocoa output supplied. Contrary to this, the results indicate that technological advances arising outside government research expenditure has a negative effect on output of cocoa supplied. In the long-run it is estimated that if technology from private sources increases by 1 %, the mean cocoa supply will decrease by 18.9 % holding all other variables constant. This result is significant at the 0.01 significance level. Technology in itself is expensive for individual farmers to purchase and adopt, this is in cognisance of the fact that almost all the farmers engaged in cocoa production are smallholders. Therefore, cocoa farmers opting to adopt private technological innovations at their own cost will reduce drastically their available resources that will be left to maintain the cocoa farm. Without extra resources to maintain the cocoa farms after purchasing such private technology, the overall output of cocoa will tend to reduce. Moreover, since government provides highly subsidised technologically advanced methods to farmers, any farmer who may wish to purchase and adopt private technological methods to gain competitive advantage may lose out since all farmers acquire such methods at highly subsided cost from the government.

4.4 Diagnostic Tests

4.4.1 Wald Test

A Wald test was conducted to check for the significance of the variables research expenditure and non-research expenditure.

Table 5: Wald Test Results

Test Statistic	Value	df	Probability
F-statistic	7.044048	(4, 6)	0.0188
Chi-square	28.17619	4	0.0000

The null hypothesis being tested is stated as:

H_0: Research expenditure in periods t-3 and t-4 as well as non-research expenditure in periods t-3 and t-2 are not significantly different from zero.

Based on the probabilities obtained we have enough evidence to reject the null hypothesis at 0.05 significance level. We conclude that research and non-research expenditures are statistically different from zero and that they cause changes in cocoa output supply.

4.4.2 Autocorrelation

To test for the presence of autocorrelation, an LM test was conducted to further back the Durbin-Watson statistic.

Table 6: LM Test Results

Lags	LM-Statistics	Prob.
1	4.170108	0.8999
2	13.94779	0.1242

The Durbin-Watson statistic of 1.673752 which is approximately 2 indicates that there is no evidence of autocorrelation. To conduct the LM test a null hypothesis is formulated as H0: no serial correlation. The probability values of 0.8999 and 0.1242 for the first and second lags respectively are both greater than our 0.05 significance level hence we fail to reject the null hypothesis. By implication there is no serial correlation in our data.

4.4.3 Breusch-Pagan-Godfrey Heteroskedasticity Test

The Breusch-Pagan-Godfrey Heteroskedasticity test is conducted based on the null hypothesis the; there is no heteroskedasticity.

Table 7: Breusch-Pagan-Godfrey Heteroskedasticity Test Results

F-statistic	**0.323920**
Prob. F (11, 4)	0.9377
Prob. Chi-Square (11)	0.7540

With the F. probability value of 0.9377 which is greater than our 0.05 significance level, we fail to reject the hypothesis of no heteroskedasticity which implies that there is the presence of homoscedasticity.

4.4.4 Stability Test

The cumulative sum (CUSUM) of recursive residuals is applied to assess parameter stability. The CUSUM test identifies systematic changes in the regression coefficients.

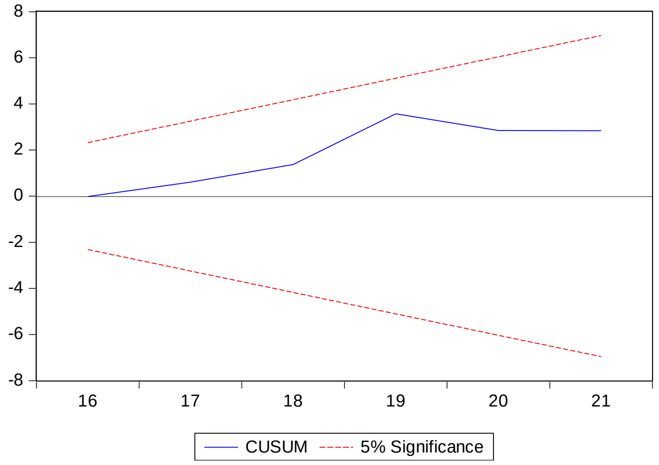

Figure 14: CUSUM Test Results

The result, Fig. 14 indicates the absence of any instability of the coefficients because the plots of the CUSUM statistic fall inside the critical bands of the 5 % confidence interval of parameter stability. This implies there exists stability in the coefficients over the period, that is, the model is dynamically stable.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The first objective of the study was to identify the components and patterns of non-research expenditure in the cocoa sub-sector. By way of conclusion, it was discovered that non-research expenditure was allocated for six distinct purposes. Allocations were made to CSSVD to tackle swollen shoot virus and later to undertake extension services. The seed production unit was to ensure the mass production of hybrid seeds for cocoa farmers. Cocoa service division was tasked to undertake extension services while the BCC was to train field and technical staff. Allocations were made to COCOBOD head office for administrative purposes as well as allocation for capital expenditure. A disaggregation of non-research expenditure into its various components revealed that during the period under study, 50% of all non-research expenditure was for administrative purposes leaving minimal portions for activities like extension, training, pest and disease control services as well as capital assets.

Research expenditure was found to affect cocoa supply both in the short- and long-run and in significant proportion. Since research expenditure had a lagged effect on cocoa supply, it was revealed that in the short-run research expenditure three years ago was more impactful on supply than that of four years ago. In the long run research expenditure positively affected cocoa supply. This conclusion is in line with existing literature which points to the productivity increasing effect of research activities.

Non-research expenditure in the short-run was found to be causing a decline in the output of cocoa supplied. An argument was made that, this must be the case due to the large share of non-research expenditure going into administrative activities instead of more to tackle pest and diseases as well as boosting extension services. In the long-run however, non-research expenditure had a positive and significant effect on cocoa output supplied largely attributable to the cumulative effect of the smaller expenditure on other non-research activities other than administrative issues.

Prices had the expected effect on supply as stipulated in theory. Increasing cocoa prices led to increasing cocoa supplied in the short-run though no it had no effect on supply in the long-run. Maize prices were found to cause decreases in cocoa supplied in the short-run but had no long-run effect on the supply of cocoa.

5.2 Recommendations

Based on the findings of this study three recommendation are made.

1. Since research expenditure on cocoa has been proven to be an effective way of increasing cocoa supply, expenditure allocated for research purposes must be increased to realise greater benefits. This can be done through increasing government cocoa research expenditure. An increase in government cocoa research expenditure will ensure an increase in cocoa research activities. The availability of funds to conduct research will invariably lead to more research outputs that will enhance cocoa production through new and improved varieties as well as ways to alleviate problems faced with cocoa farmers.
2. The negative effect non-research expenditure had on cocoa supply in the short-run points to the lack of better targeting of non-research expenditure. By implication government must identify and increase expenditure on other critical non-research activities such as disease control, staff training, extension services and subsidised inputs.

3. Since cocoa prices have proved to be a crucial factor affecting the level of cocoa supply. Government must ensure that the Cocoa Price Review Committee that set cocoa prices in Ghana ensure that a favourable percentage of the Free-On-Board (FOB) cocoa prices are offered to Ghanaian cocoa farmers. This will go a long way to ensure that in the short-run cocoa output supplied will increase.

5.3 Limitations of the Study

Even though many efforts have been made to conduct a thorough study of the research problem, this study suffered from two limitations.

Firstly, the absence of a complete and continues data on expenditure for all non-research activities prevented modelling the supply function taking into consideration each of such non-research activities so as to capture their exact impact on supply of cocoa.

Secondly, the current study was limited in capturing all the factors, be it, institutional, economic or social that may have an impact on the supply of cocoa in Ghana considering the complex nature of the cocoa sub-sector in Ghana.

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APPENDICES

Appendix 1: Augmented Dickey-Fuller Unit Root Test on D (CocoaQ)

Null Hypothesis: D(CocoaQ) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.332151	0.0001
Test critical values:	1% level	-3.857386	
	5% level	-3.040391	
	10% level	-2.660551	

Augmented Dickey-Fuller Test Equation Dependent
Variable: D(CocoaQ,2)
Method: Least Squares
Sample (adjusted): 3 20
Included observations: 18 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CocoaQ(-1))	-1.425937	0.225190	-6.332151	0.0000
C	31128.41	30778.96	1.011353	0.3269

R-squared	0.714775	Mean dependent var	-1966.389
Adjusted R-squared	0.696949	S.D. dependent var	233764.7
S.E. of regression	128687.7	Akaike info criterion	26.47260
Sum squared resid	2.65E+11	Schwarz criterion	26.57153
Log likelihood	-236.253	Hannan-Quinn criter.	26.48624
F-statistic	40.09614	Durbin-Watson stat	2.160239
Prob(F-statistic)	0.000010		

Appendix 2: Augmented Dickey-Fuller Unit Root Test on D (CocoaP)

Null Hypothesis: D(CocoaP) has a unit root

Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.861583	0.0697
Test critical values:	1% level	-3.857386	
	5% level	-3.040391	
	10% level	-2.660551	

Augmented Dickey-Fuller Test Equation Dependent Variable: D(CocoaP,2) Method: Least Squares
Sample (adjusted): 3 20
Included observations: 18 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CocoaP(-1))	-0.676176	0.236294	-2.861583	0.0113
C	292.6144	279.9219	1.045343	0.3114

R-squared	0.338533	Mean dependent var	5.627606
Adjusted R-squared	0.297191	S.D. dependent var	1322.582
S.E. of regression	1108.769	Akaike info criterion	16.96433
Sum squared resid	19669904	Schwarz criterion	17.06326
Log likelihood	-150.6790	Hannan-Quinn criter.	16.97797
F-statistic	8.188659	Durbin-Watson stat	1.831041
Prob(F-statistic)	0.011307		

Appendix 3: Augmented Dickey-Fuller Unit Root Test on D (MaizeP)

Null Hypothesis: D(MaizeP) has a unit root

Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.096338	0.0008
Test critical values:	1% level	-3.857386	
	5% level	-3.040391	
	10% level	-2.660551	

Augmented Dickey-Fuller Test Equation Dependent Variable: D(MaizeP,2) Method: Least Squares
Sample (adjusted): 3 20
Included observations: 18 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(MaizeP(-1))	-1.244790	0.244252	-5.096338	0.0001
C	41.47085	49.67079	0.834914	0.4161

R-squared	0.618800	Mean dependent var	-12.59994
Adjusted R-squared	0.594974	S.D. dependent var	323.4860
S.E. of regression	205.8717	Akaike info criterion	13.59682
Sum squared resid	678130.8	Schwarz criterion	13.69575
Log likelihood	-120.3714	Hannan-Quinn criter.	13.61046
F-statistic	25.97266	Durbin-Watson stat	2.047590
Prob(F-statistic)	0.000108		

Appendix 4: Augmented Dickey-Fuller Unit Root Test on D (OilpP)

Null Hypothesis: D(OilpP) has a unit root

Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.129950	0.0008
Test critical values:	1% level	-3.857386	
	5% level	-3.040391	
	10% level	-2.660551	

Augmented Dickey-Fuller Test Equation Dependent Variable: D(OilpP,2) Method: Least Squares
Sample (adjusted): 3 20
Included observations: 18 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(OilpP(-1))	-1.237013	0.241136	-5.129950	0.0001
C	14.97848	16.84444	0.889224	0.3871

R-squared	0.621896	Mean dependent var	-6.058272
Adjusted R-squared	0.598264	S.D. dependent var	109.3593
S.E. of regression	69.31476	Akaike info criterion	11.41963
Sum squared resid	76872.58	Schwarz criterion	11.51856
Log likelihood	-100.7767	Hannan-Quinn criter.	11.43327
F-statistic	26.31639	Durbin-Watson stat	2.030378
Prob(F-statistic)	0.000101		

Appendix 5: Augmented Dickey-Fuller Unit Root Test on D (NonResExp)

Null Hypothesis: D(NonResExp) has a unit root

Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.979524	0.0001
Test critical values:	1% level	-3.857386	
	5% level	-3.040391	
	10% level	-2.660551	

Augmented Dickey-Fuller Test Equation Dependent
Variable: D(NonResExp,2) Method:
Least Squares
Sample (adjusted): 3 20
Included observations: 18 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(NonResExp(-1))	-1.390717	0.232580	-5.979524	0.0000
C	30945028	27331137	1.132226	0.2742

R-squared	0.690849	Mean dependent var	-2528871.
Adjusted R-squared	0.671527	S.D. dependent var	1.98E+08
S.E. of regression	1.13E+08	Akaike info criterion	40.03690
Sum squared resid	2.06E+17	Schwarz criterion	40.13583
Log likelihood	-358.3321	Hannan-Quinn criter.	40.05054
F-statistic	35.75471	Durbin-Watson stat	2.103754
Prob(F-statistic)	0.000019		

Appendix 6: Augmented Dickey-Fuller Unit Root Test on D (ResExp)

Null Hypothesis: D(ResExp) has a unit root

Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.383309	0.0005
Test critical values:	1% level	-3.857386	
	5% level	-3.040391	
	10% level	-2.660551	

Augmented Dickey-Fuller Test Equation Dependent
Variable: D(ResExp,2) Method:
Least Squares
Sample (adjusted): 3 20
Included observations: 18 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(ResExp(-1))	-1.302634	0.241977	-5.383309	0.0001
C	4463975.	3495175.	1.277182	0.2198

R-squared	0.644286	Mean dependent var	-411745.7
Adjusted R-squared	0.622054	S.D. dependent var	23296820
S.E. of regression	14322252	Akaike info criterion	35.89697
Sum squared resid	3.28E+15	Schwarz criterion	35.99590
Log likelihood	-321.0727	Hannan-Quinn criter.	35.91061
F-statistic	28.98001	Durbin-Watson stat	2.061745
Prob(F-statistic)	0.000061		

Appendix 7: Augmented Dickey-Fuller Unit Root Test on D (RAIN)

Null Hypothesis: D(AVE_RAIN) has a unit root

Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.160744	0.0000
Test critical values:	1% level	-3.857386	
	5% level	-3.040391	
	10% level	-2.660551	

Augmented Dickey-Fuller Test Equation Dependent
Variable: D(RAIN,2)

Method: Least Squares
Sample (adjusted): 3 20
Included observations: 18 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(RAIN(-1))	-1.577163	0.220251	-7.160744	0.0000
C	-0.947322	2.504234	-0.378288	0.7102

R-squared	0.762175	Mean dependent var	-0.914929
Adjusted R-squared	0.747311	S.D. dependent var	21.13571
S.E. of regression	10.62455	Akaike info criterion	7.668650
Sum squared resid	1806.096	Schwarz criterion	7.767581
Log likelihood	-67.01785	Hannan-Quinn criter.	7.682292
F-statistic	51.27626	Durbin-Watson stat	2.096550
Prob(F-statistic)	0.000002		