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AN EMPIRICAL ANALISIS OF THE IMPACT OF CLIMATE CHANGE ON COCOA PRODUCTION IN SELECTED COUNTRIES IN WEST AFRICA

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ABSTRACT

The study examined the impact of climate change on cocoa production in Ghana, Nigeria and Cote D'Ivoire from 1969 to 2009. A translog production function based on agronomic ideas was employed. The model was estimated using time series data with the Engle-Granger Error Correction Technique (ECM). The result shows that the two climatic variables, their lags and interaction with other leading variables have various degrees of impact on cocoa output in the selected countries. The ECM showed different speed of adjustment to long run equilibrium. It is therefore recommended that the authorities in these countries develop adaptation strategies that would fit into local climatic conditions. This could take the form of extension services to enhance the maintenance of cocoa shade that contributes to buffering temperatures and also improve hydrological cycling. Establishment of irrigation systems in farms through the provision of infrastructure, education and training for cocoa farmers are also encouraged.

Keywords: Climate change, cocoa output, time series data, translog, Engle-Granger ECM.

INTRODUCTION

Cocoa is one of the major agricultural exports from West Africa. The sub-region contributes about 70% of the world market of Cocoa. In terms of annual production size, the eight largest cocoa-producing countries at present are Côte D'Ivoire, Ghana, Indonesia, Nigeria, Cameroon, Brazil, Ecuador and Malaysia. These countries represent 90 percent of world production. Production from Côte D'Ivoire alone is 40 percent of the world's market share and constitutes 1.2 million metric tonnes per annum (UNCTAD, 2009). In 2000, raw cocoa represented 80 percent of the Côte D'Ivoire's commodity exports, over 50 percent of all exported goods and services, and 21 percent of GDP (Bogetic, Noer and Espina, 2007). Currently, Ghana and Nigeria contribute 20.98 percent and 6.7 percent respectively to the World Market (Lundstedt and Pärssinen 2009, ICCO, 2009). Overall, these three countries contribute a total of 67 percent of World Market Share of cocoa and yields considerable revenue to these economies. These countries enjoy part of the world production of 3 million tonnes with exports of the beans and semi-processed products valued at more than US $5 billion annually (Lueandra and Jacque, 2007).

Incidentally, a brief overview of the scientific evidence on climate change and its impacts on agriculture show the subject is compelling and continues to evolve. The Fourth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC 2007a) stated that the planet's climate is indisputably warming, and the Stern Review (2006) on the economics of climate change concludes that climate change presents very serious global risks and this demands an urgent global response. With the global rise in temperature, local rainfall patterns are changing, ecological zones are shifting, the seas are warming and ice caps are melting (IPCC, 2007 b). Developing countries are currently at a double disadvantage, because the tropical areas stand to experience some of the most severe impacts of climate change, and agriculture which is the sector most sensitive to climate change, is expected to be immediately impacted. Whereas increasing global temperature is likely to boost agricultural production in the temperate regions, it is expected to reduce yields in the tropical regions of the world (UNEP-WTO Report, 2009). According to the IPCC report, (2007a), it is projected that many regions of Africa will suffer from droughts and floods with greater frequency and intensity in the nearest future and that, the rise in average temperature between 1980/1999 and 2080/2099 would be in the range of 3 - 4°C across the entire African continent; that is 1.5 times more than the global level.

West Africa has a high vulnerability profile in terms of natural, economic and social systems, and due to this, climate change is expected to affect all the means of livelihood of the populations. Ominde and Juma (1991) underlined Africa's high vulnerability to climate change because of its heavy dependence on agriculture and limited coping capacity. Even best-case scenarios (Reilly and Hohmann, 1994) forecast adverse effects of agricultural damage on the wellbeing of consumers in Africa. All forecasts indicate that climate change will result in the deterioration of living conditions on the continent (DFID, 2006). Evidence from the UNCTAD 2009 report has already shown that prices of tropical beverages propped up due to crop shortages in major producing areas following from adverse weather conditions. This is the case for coffee in Colombia, Central America and Brazil, cocoa in Côte D'Ivoire and Ghana, and tea in India, Kenya and Sri Lanka – evidences of climate shocks. The crisis brought about by the spiraling prices of agricultural commodities throughout the world has recently been intensified by the vulnerability of tropical regions to climate hazards. According to CIRAD, a Paris-based research institution, global prices of cocoa have risen in part because Côte D'Ivoire, which usually grows 1.3 million metric tonnes per annum, endured a torrid 2008/09 season (Doguma, 2010).

What then is the current state of impact of climate change on cocoa production in West Africa? What is the likely future state of cocoa producing economies in West Africa? How should these countries manage any future impact that could occur? Studies on the impact of climate change on the arable crops are vast but those on cocoa are inchoate in the literature. The little attention on cocoa are also limited in time frame, scope and inconclusive. This study, therefore, tried to find answers to these empirical questions. The overall objective of the study is to determine the impact of climate change on cocoa production in the selected countries in West Africa.

BACKGROUND

This section essentially discusses the prevailing agronomic conditions for cocoa production in the region. Moreover, the section explains the demand and supply of cocoa between the region and the rest of the world. Policies relating to cocoa production and export are also dilated in this section. The last part of the section embarks on trend analysis of the climatic variables and cocoa output in the region.

The Ecosystem of West Africa

West Africa has rich ecosystems that vary from semi-desert and savannah to tropical forests, mangroves, rivers, freshwater lakes, and marshes. The Guinean forest, extending from the west of Ghana, through Côte D'Ivoire, Liberia, Guinea and the south of Sierra Leone, is a unique ecosystem in the world and is considered to be a world priority ('hotspot') in the conservation literature. This ecosystem provides a habitat for many species of flora and fauna. Within this stretch is the high forest zone which is a good belt for cocoa production. This "quasi-virgin" geographic area allows the most of the region's comparative advantages (ECOWAP, 2009) in crop production.

The region occupies a leading position in the production of cocoa, coffee, cotton, palm oil, cashew nuts and oilseeds-sesame, shea and groundnut. Agricultural products exported from the region are essentially raw materials subject to little or no processing, most of which are exported to Europe (coffee, cocoa, fish, citrus fruit, cut flowers, and so on) or to Asia (cotton). Cocoa alone accounts for 20 percent of the region's total exports to the European Union (ECOWAS, WAEMU & EU, 2008) and generates work opportunities for an estimated 10.5 million Africans (ICCO, 2003).

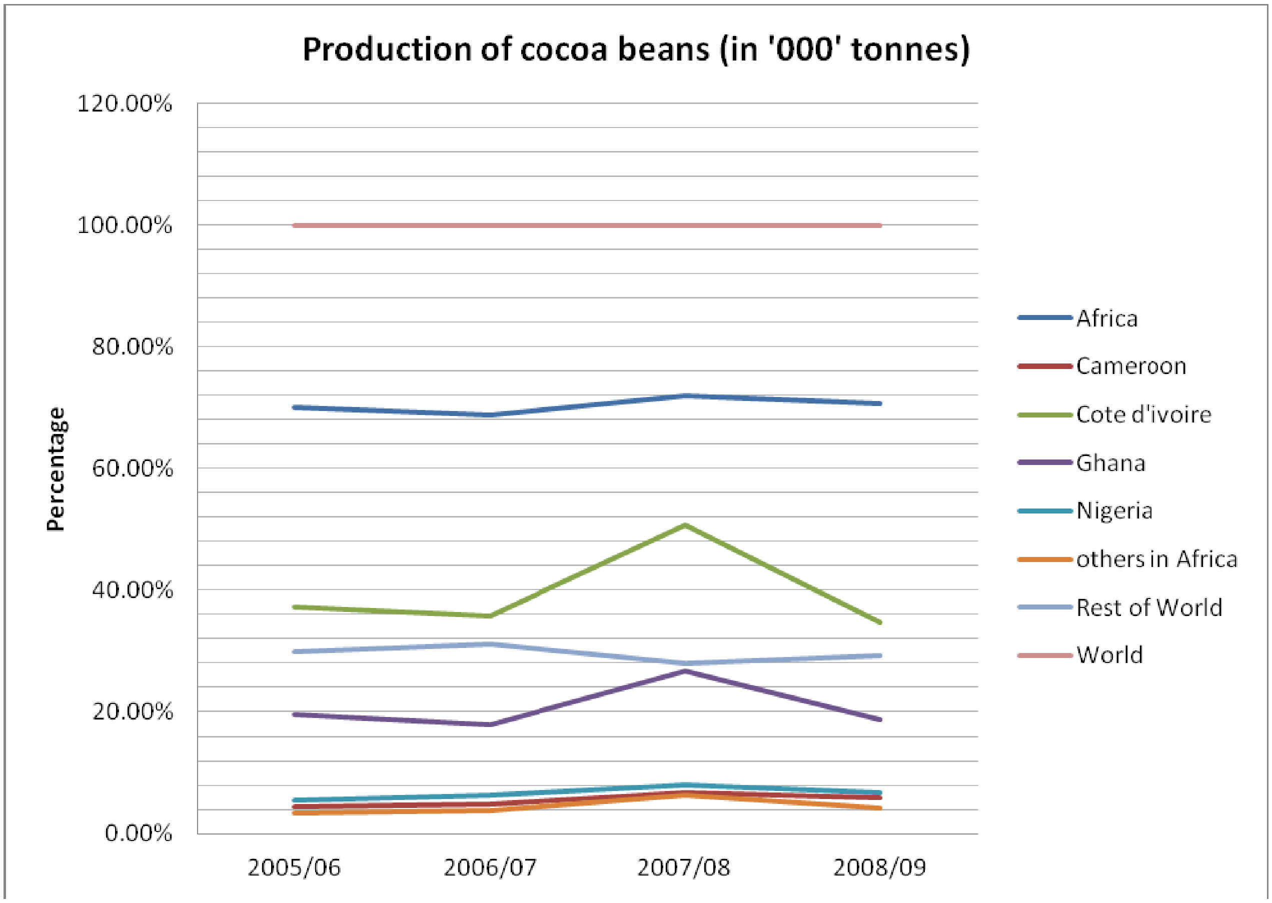
The Economics of Cocoa Production in West Africa

Cocoa, a tropical perennial tree crop, is the product of the fruit of the cocoa tree. Cocoa flourishes well only in hot, rainy climates with cultivation generally confined to areas not more than 20 degrees north or south of the equator. A mean shade temperature of 27°C, with daily variation less than 8°C, and well-distributed rainfall of at least 12 cm are the ideal climatic conditions for the growth of cocoa (Kishore, 2010). Annual rainfall between 1,100mm and 3,000mm with a dry season not more than three months with the minimum rainfall level of about 100mm per month is required for good output. The cocoa itself is grown from seedlings raised in nurseries; more usually, it is grown directly from seed. When the seedlings grow to a height of about 5 cm. or so, they are transplanted at a distance of about 3 or 4 meters (Lundstedt et al, 2009). The planters also grow shady plants, in between the rows, in order to protect the young plants from strong winds and direct rays of the Sun. The most commonly grown type of cocoa may give a first small yield after about five years, though the period considerably varies with local conditions and farming methods. But a full crop cannot be expected for at least ten years. The economic life span of the cocoa tree is not known; but under the best conditions of weather, soil and management, it can be kept almost in indefinitely bearing (Kishore, 2010).

Supply of Cocoa from West Africa

The world production of cocoa beans has experienced irregular pattern due to heavy dependence on weather in production, low farm-gate prices, pests and diseases. For example, in 2003/04 season, the global production of cocoa beans continued to rise for the fourth successive year, with output exceeding the recorded production levels of 2002/03 by almost 10 percent to reach 3.5 million tons (ICCO, 2003). ICCO spelt out in their 2003/04 report that, Cote D'Ivoire defied fears of decline and instead recorded a substantial increase to reach 1.4 million tons, despite two years of political and social unrest. During the same season, good weather, higher farm gate prices, combined with effective government-backed of mass spraying of crops contributed to a substantial increase in yields, propelling Ghana's output to a record of 736,000 tons. However, during 2006/07 season, world production dropped by almost 9 percent from the previous season to 3.4 million tons, mainly as a consequence of unfavorable weather conditions in many cocoa producing areas (ICCO Annual Report, 2006/07). A statistical summary of cocoa production in Sub-Saharan African countries are reported in figure 1.

Figure 1: The Size of Cocoa Output produced from West Africa.

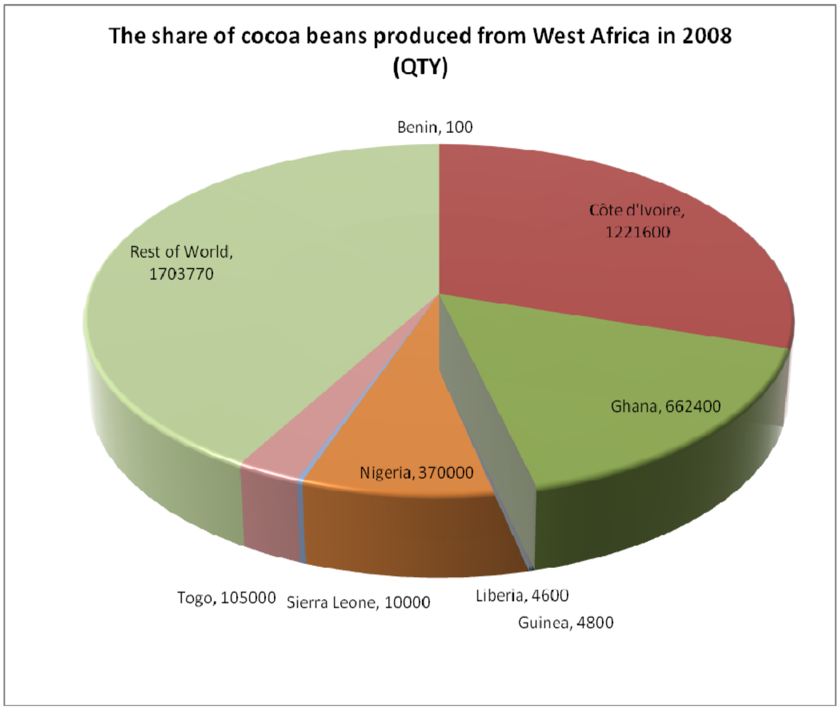


Data Source: ICCO Quarterly Bulletin of Cocoa Statistics, Vol. XXXV, No.4, Cocoa year 2008/09, plotted by Author, 2011.

It is evident from Figure 1 that the sampled countries have dominated the production and exports of cocoa bean over the period under review. From a modest beginning in the 1950's, Cote D'Ivoire overtook Ghana as a leading producer of cocoa beans from the mid of 1970's and has still maintained its lead.

The domination of West Africa in terms of production of cocoa beans connotes how shortage of supply could influence the world market. For example, figure 2 below shows that, in 2008/09 season, while a total of 4,082,270 metric tonnes of cocoa beans produced globally, the eight cocoa producing countries in West Africa together contributed 2,378,500 metric tonnes with the remaining 1,703770 contributed by the rest of the world. Out of the share contributed by West Africa, Cote D'Ivoire alone contributed 1,221,600 metric tonnes (Mt), followed by Ghana with 662,400 Mt and then Nigeria with 370,000 Mt. The other producers in West Africa contributed 105,000 Mt, 10,000 Mt, 100 Mt, 4,600 Mt and 4,800 Mt, respectively for Togo, Sierra-Leone, Benin, Liberia and Guinea.

Figure 2: The share of cocoa beans produced from West Africa in 2008



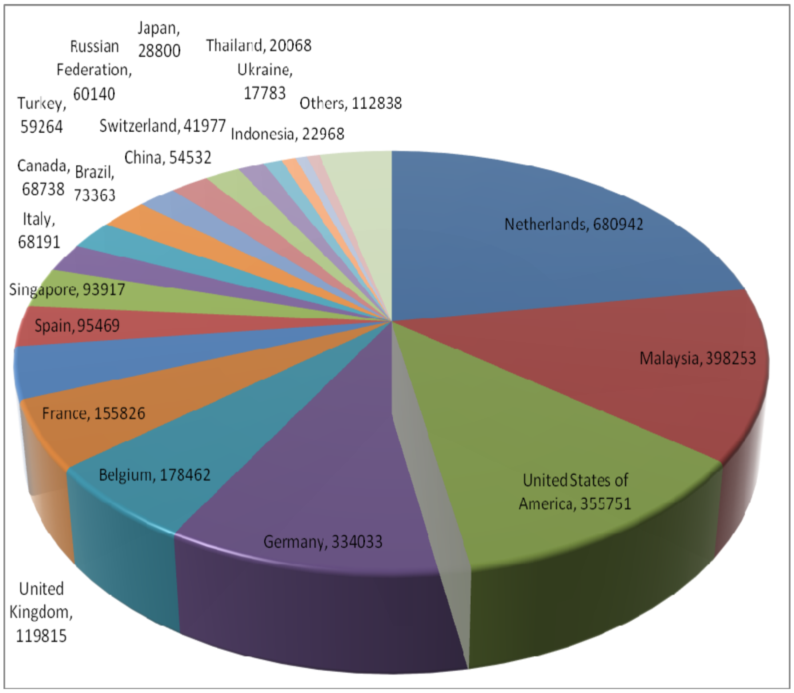
Source: Data from FAO site, plotted by Author, 2011.

World Market's Demand of Cocoa from West Africa

Cocoa is predominantly consumed in countries of relatively high income. The amount of cocoa ground for use (known as the quarterly cocoa "grind") is traditionally used to measure consumption trends. Higher grind figures signify rising demand. However, intermediate consumption and final consumption are considered better measures for estimating cocoa consumption on national basis (ICCO, 2009).

According to ICCO report (2009), whereas crop years 1998/99 to 2007/08 had a global cocoa production increased from around 2.8 million tonnes to 3.7 million tonnes, with an average annual growth rate of 2.7 percent, consumption showed similar patterns, with an average annual increase of 2.9 percent, from 2.9 million tonnes to 3.7 million tonnes. The report shows that between 1980 and 2007 there was a balance in the demand and supply of cocoa in the world market. A surplus or shortage can lead to erratic prices long before the cash market can adjust to the supply of cocoa. Historical trend of cocoa cash price during the period 1966-2009 has shown that cocoa spot prices at expiration exhibit unpredictable pattern.

Figure 3: Share of main consuming countries in 2009 (Qty)



Source: UNCTAD (2009) - based on the data from International Cocoa Organization, quarterly bulletin statistics, plotted by author, 2011.

Policies on Cocoa Production and Export in West Africa

Historically, the former colonial powers, France and Great Britain established stabilization funds and marketing board systems. These parastatals controlled farmgate prices, input supply and all levels of marketing, research and extension (Dand, 1999; Fold, 2002). The French and English influences from their colonial past led each country to follow either a *Caisse de Stabilisation* or marketing board approach, respectively. The marketing boards in Ghana and Nigeria controlled all aspects of the cocoa marketing chain by setting the price in the pre-season, and by declaring producer prices, buyer's margins, transportation costs and export taxes. The marketing boards also performed all the related tasks including inspections, buying, loading, transportation, quality control, storage and export. The *Caisse*, in Ivory Coast and Cameroon, on the other hand, was not directly involved with the transportation of cocoa from the farmgate (controlled by private traders called *traitants*) and permitted 'private' exporters to operate within a system of quotas (Fold, 2002), and regulated farm gate as well as export prices, while collecting substantial taxes.

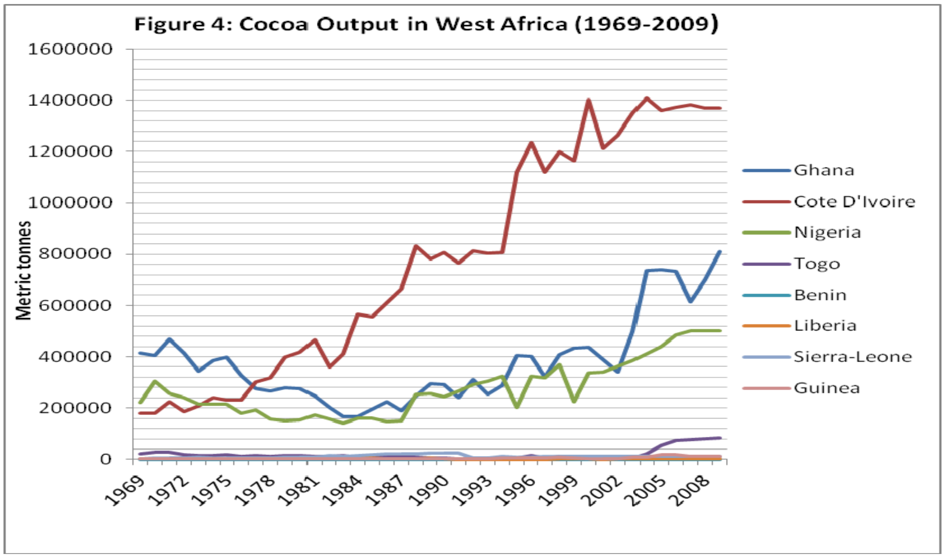
These systems turned out to be inefficient and their inefficiency even further aggravated after independence was gained, leading to large costs of operations mainly paid by cocoa producers. This necessitated liberalization of the cocoa sector (Varangis and Schreiber, 2001). Also, as a condition for the Structural Adjustment Programmes, the World Bank in the early 1980s required reforms of the cocoa sectors, in order to diminish operation costs and raise producer revenues. A free market system was thought to give farmers better prices in the long term. All cocoa producing countries in West Africa undertook some reforms – Nigeria, Togo and Cameroon reformed the whole system, while Côte D'Ivoire and Ghana chose a more partial and gradual approach to liberalization. In some West African countries, the liberalization has resulted in the elimination of parastatals and created the need for new private institutions and market agents to replace the services of those government agencies (Bloomfield and Lass, 1992; Varangis *et al*, 2001). Initially, chaotic markets characterized by entry of many exporters emerged, but multinational cocoa bean processors recently took over exporting as well as processing and are serving backward integrating into domestic links of the cocoa supply chain.

Analysis of Trend in Cocoa Production in West Africa

Figure 4 reports trends of cocoa production by the major West African producers from 1969 to 2009. Generally, whilst there has been an increasing trend of cocoa output among the major producers, the minor producers have had fairly constant production across the study period. The figure also shows dwindling occurrences along the production path of the three major producers, namely, Ghana, Cote D'Ivoire and Nigeria. In specific terms, the production trajectory of Cote D'Ivoire has witnessed increasing trend throughout the study period. Ghana, which was the leading producer among the countries in West Africa started envisaging low production from the early seventies till 1984 when it started rising to date. Nigeria's output was higher than that of Cote D'Ivoire in the early stages of the 60's but after 1970 output started declining till the late 1980's when it started increasing again till date. Ghana and Nigeria have followed similar patterns of output growth over the years except for quantity. An important feature on the graph is the precipitous fall that occurred in the 1983-84 cocoa season among all the countries. This period earmarked the most torrid season in West Africa over the years.

The remaining five countries have had similar production levels throughout the study period except for fluctuations among them. The output of Togo has witnessed some episodic rise from 1984 to the present day.

Figure 4: Analysis of trends in cocoa production in West Africa.

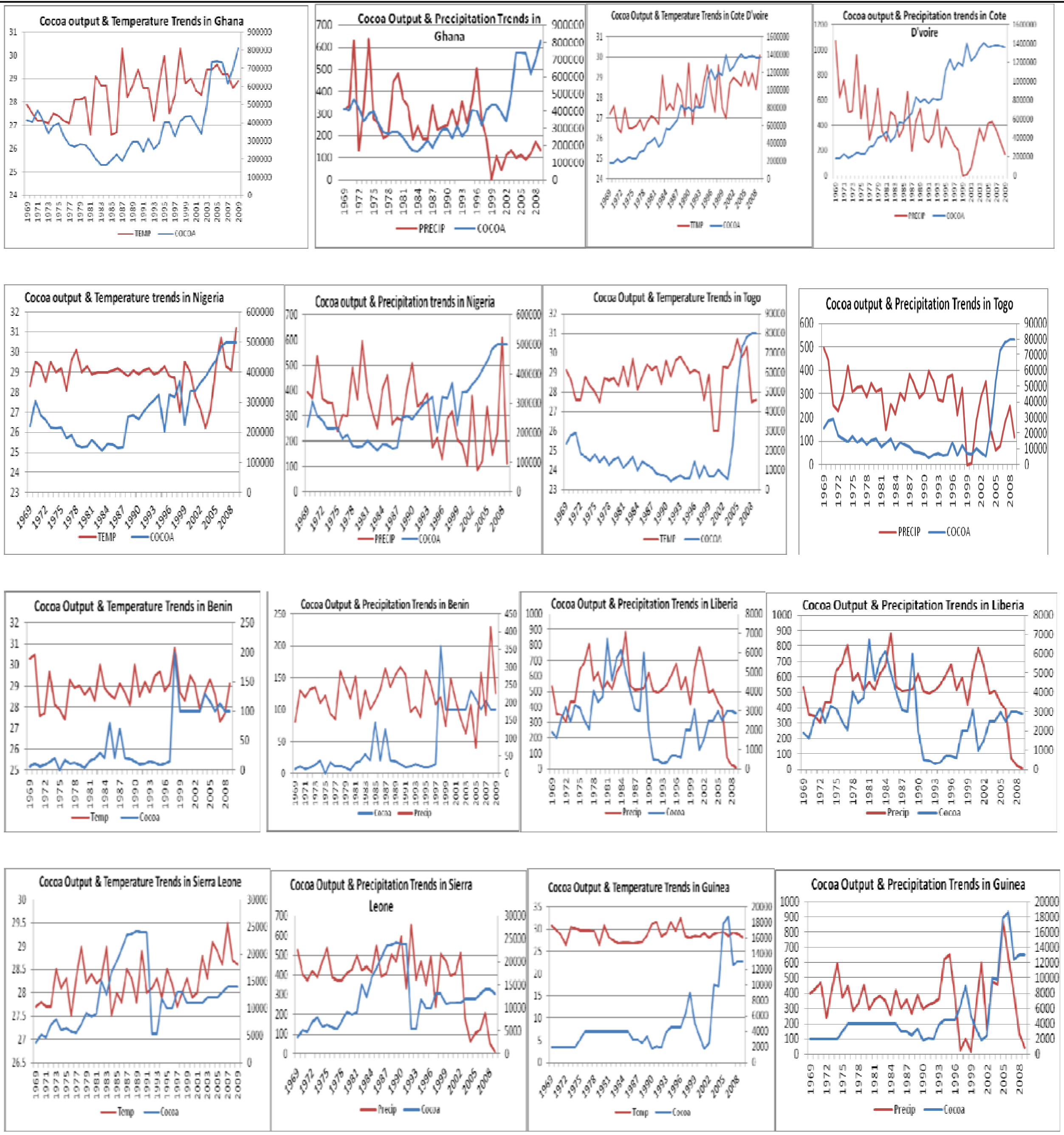


Source: data from FAO site and plotted by Author, 2011.

Analysis of trends in Cocoa output and selected climatic variables

The variables under consideration were temperature and precipitation. The temperature and precipitation data used here are those of the cocoa producing areas instead of the country meteorological data.

Figure 5: Trend Analysis of Cocoa output and Selected Climatic Variables in the Selected Countries.



Source: FAO Climpag data plotted by the Author, 2011.

The graphs on all these countries indicate that temperature has been rising overtime. In terms of precipitation, there has been declining trend throughout the study period for all the countries. Cocoa output on the other hand has been increasing across all the countries and over the study period.

Correlation Analysis of Cocoa output and the Climatic Variables

Table 1 reports the correlation analysis of the three selected cocoa producing countries in West Africa. The table uses the minimum and the maximum climatic values to ensure comparison. The data are temperature and precipitation for a period of forty-one years. Also worth noting is that there are two sets of data comprising country wide specific climatic data and cocoa producing data set from the specific countries under study. In this analysis the data on the producing areas were used instead of country data set.

Table 1: Correlation Analysis of Cocoa and Climatic Variables in the selected Countries.

Variable	Min Temp	Max Temp	Min Precip	Max Precip	Country
Cocoa Output	0.15(0.34)	0.18(0.263)	0.56(0.000)**	-0.58(0.00)**	Ghana
Cocoa Output	0.18(0.269)	0.45(0.003)**	0.28(0.081)	-0.61(0.00)**	Cote D'Ivoire
Cocoa Output	-0.20(0.248)	0.61(0.00)**	0.20(0.22)	-0.67(0.00)**	Nigeria

Source: Data from FAO site and plotted by Authors, 2011.

Considering the values for Ghana, it is clear from the Pearson Correlation Analysis that there is a positive co-variation between cocoa production and the two major climatic variables under consideration. There is a perfect negative significant correlation between cocoa output and maximum precipitation. While minimum precipitation is significant it fairly co-varies with cocoa output within the period of study. Both minimum and maximum temperatures are, on the other hand, not significant and weakly co-vary with cocoa output in the case of Ghana.

Cote D'Ivoire's case is quite different from that of Ghana as depicted in table 5. Maximum precipitation and maximum temperature co-vary well with cocoa output for Cote D'Ivoire. The table shows that there is a perfect negative significant co-variation between cocoa output and maximum precipitation, and a perfect positive significant correlation between maximum temperature and cocoa output. However, the table shows that minimum temperature and precipitation weakly co-vary with cocoa output. They are also insignificant with minimum temperature having incorrect sign in line with the literature.

In Nigerian case, both maximum temperature and precipitation are perfectly significant, have the right signs and fairly co-vary with cocoa output. In the table, Nigeria shows that both minimum precipitation and temperature are insignificant, have the opposite signs and weakly co-vary with cocoa output.

LITERATURE REVIEW

This section presents a review of relevant theoretical and empirical literature relating to the impact of climate change on cocoa production in West Africa.

Theoretical Underpinnings

There are four major theories that underpin climate change and crop production; namely the Ricardian theory, crop yield response theory, the Agricultural Investment Portfolio Model (AIPM) and the Metaeconomics Theoretical Model (MTM).

The Ricardian theory is founded on Ricardo's original observation that the value of land reflects its productivity. It is modeled in a cross-sectional fashion such that the technique enables the measurement of the determinant of farm revenue. The AIPM reflects farmer risk aversion of weather and leans on the Von Neumann-Morgenstern (VNM) theory. The model assumes that farmers cannot insure against any risk ex ante and cannot perform any consumption smoothing ex post (Just and Pope, 1978; Antle et al, 1987 & 1989). The basis of the theory is that farmer utility depends on farm income, so that farmer consumption variability is isomorphic with farm profit variability. It therefore visualizes weather variables as risk to the farmer due to the nature of the uncertainties involved. The underlying precept of the metaeconomic theoretical model is on how much influence weather information forecasts have on decisions of farmers.

The Crop Yield Response theory allows for weather influence upon crops in agricultural production analysis. It is based on the works of Lang (1920), Koppen (1918), Martonne (1926), Angstrom (1936) and Thornthwaite (1948). The method combines precipitation and temperature into composite "aridity" indexes. The theory conceives that output is generally through a production function to land, labor and capital. However, the direct application of such a general function to agriculture neglects the existence of weather as an important exogenous factor. As a result, the theory considers rainfall, temperature and sun radiations as well as many other weather factors as "noncost" inputs, into the production process especially when they are taken as deviations from average. The setup assumes a log-normal distribution of W such that in Cobb-Douglas specification the equation is written as:

$$P = aL^{1}N^{n}K^{k}W^{w} \qquad (1)$$

Where a is a constant term, P =Output, L =Land, N =Labour, K =Capital, W =Weather Index, $l, n, k,$ and w are the coefficients of constant elasticity of output to each input factor. Under normal weather conditions, W =1, and log$W$ =0.

The use of other functional forms is also explicit in the literature to capture climatic variables. In translog formation the weather element is encapsulated in the x_i input variables as:

$$InP = \alpha + \sum \beta_i Inx_i + \sum_i \sum_j \delta_{ij} (Inx_i)(Inx_j) \qquad (2)$$

Where P is output, x_i and x_j are the set of inputs including weather variables. Other applicable functional forms that fit into the crop response theory include quadratic, square root, Mitscherlich-Baule (or MB) as well as the linear and non-linear Von-Liebig functions. The rationale for choosing a particular functional form depends on the research questions and the underlying production processes to be modeled (Nkonya, 1999).

Empirical Literature

At the micro level, two methods to finding the impact of climate change on crop revenue in general are discernible. First, Ricardian Method (RM), regress climatic variables such as temperature and precipitation on farm yields. It is a cross-sectional technique that measures the determinants of farm revenue. It is based on Ricardo's original observation that the value of land reflects its productivity (Asafu-Adjaye, 2008). As cited in Seo, Mendelsohn and Munasinghe (2005), the RM accounts for the direct impact of climate on yields of different crops as well as the indirect substitution of different inputs, introduction of different activities, and other potential adaptation activities by farmers to different climates. Thus, the greatest strength of the model is its ability to incorporate the changes that farmers would make to fit their operations to climate change (Mendelsohn and Dinar, 1999). The major flaws are (i) crops are not subject to controlled experiments across farms (ii) it does not account for future change in technology, policies and institutions, (iii) assumes constant prices which is really not the case with agricultural commodities since other factors determine prices; and, (iv) fails to account for the effect of factors that do not vary across space such as CO_2 concentrations that can be beneficial to crops (Kaiser et al. 1993). This method has been extensively used in most studies in Africa to assess the economic impact of climate change on crop yields (see for example, Molua and Cornelius, 2007, Kabubo-Mariara and Karanja, 2007, Kurukulasuriya and Mendelsohn, 2007, and De, 2009).

Second, Reduced Form Crop Model (RFCM), on the other hand, is a process-based model derived from a summary statistical estimate based on an agronomic model of crop growth coupled with a linear-programming model of the US farms (Mendelsohn and Neuman, 1999). It employs a combination of: (i) controlled experiments on specific crops grown in a field or laboratory setting under different climate scenarios such as temperatures, precipitations, and or carbon-dioxide; (ii) agronomic modeling; and, (iii) economic modeling, to predict climate impact (Adams and McCarl, 1990). The estimated changes in the experimental crops from the agronomic models are then entered into an economic model to predict crop choice, production, and market prices (Seo et al. 2005). One major advantage of this method is that it directly predicts the way climate change affects crop yields since it carefully requires calibrated controlled experiments. However, its disadvantages which limits its applicability to developing countries include amongst others: (i) agronomic estimates do not control for adaptation to changing climates (Mendelsohn and Dinar, 1999); and, (ii) lack of sufficient controlled experiments to determine agronomic responses in several developing countries (Seo et al. 2005). Studies that have adopted this technique include those of Adams et al. (1989, 1993, and 1999); Easterling et al. (1993); Rosengweig and Parry, (1994); El-Shaer *et al*. (1997); Kapentanaki and Rosengweig (1997); Iglesias et al. (1999); Kumar and Parikh (2001) and so on.

Further, the translog functional form has been widely used in the methodological literature to assess the impact of climate change on crop yields. Belanger et al. (2000) compared the performance of three functional forms (quadratic, exponential and square root) to the translog in assessing crop yield and concluded that although the quadratic form is the most favoured in agronomic yield response analysis, it tends to overstate the optimal input level, and thus underestimating the optimal profitability. Other studies that have reached similar conclusions include Bock and Sikora (1990), Angus et al. (1993) and Bullock and Bullock (1994). Most studies therefore prefer the application of the translog in assessing crop yield. It is usually of the form:

$$In(\frac{q}{q^{'}}) = \alpha_o + \sum_{i=1}^{n} \alpha_i \ln(\frac{x_i}{x_i^{'}}) + \frac{1}{2}\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} \beta_{ij} \ln(\frac{x_i}{x_i^{'}}) \ln(\frac{x_j}{x_j^{'}}) + \sum_{k+1}^{m} \gamma_k Z_k + \varepsilon_i \qquad (3)$$

$\varepsilon_i \sim N(0,\sigma^2)$ Where q is the yield (kg/ha), x_i are the variable inputs (fertilizer, labour and seed), z is a vector of productivity shifters such as land husbandry practices (i.e. weeding and date of planting) as well as rainfall inputs. The most important aspect of the use of translog production function in crop yield studies is that it allows for the incorporation of climatic variables as direct inputs into the production process. The methodological literature identifies two key reasons for the choice of the translog over the other functional forms as: first, it is the best investigated second order flexible functional form and certainly one with the most applications (Sauer et al. 2004); second, it is convenient to estimate and proved to be a statistically significant specification for economic analysis as well as a flexible approximation of the effect of input interactions on yield.

Specific studies on the impact of climate change on cocoa production are inchoate in the methodological literature, but research is ongoing. Three major methods are discernible in the literature. These are the questionnaires and interview approach, general circulation model and cocoa physiological simulation model and correlation analysis method.

With regards to the questionnaire approach a research work focused on the effect of climate change on cocoa yield in Cocoa Research Institute of Nigeria (CRIN), Nigeria, was undertaken by Ajewole and Sadiq (2010). The effect of two major weather parameters, rainfall and temperature were evaluated on cocoa yield over ten years. The methodology adopted was questionnaire approach to selected cocoa farmers in the catchment area. A secondary data was also used to augment the primary data collected directly through questionnaires and interview of farmers.

In modeling the demand and supply of cocoa in Nigeria, Kareem et al (2010) incorporated climate as one of the determinants. Structured questionnaires were prepared and administered among the Nigerian cocoa farmers, agro-allied industries, and research institutes in identified 13 states where cocoa produce are abundant. In the study, cocoa output supply and demand were modeled using multiple regression method. First, relationships among supply and other influencing factors (percentage changes in population of farmers, climate, and level of mechanization) were established, then the demand and its factors (percentage changes in population of customers, income and price). Second, coefficient of determination and standard errors were determined using Statistical Software for Social Sciences (SPSS).

Oyekale, Bolaji and Olowa (2009), researched on the effects of climate change on cocoa production and vulnerability assessment in Nigeria. The focus of their work was on seedling mortality, production and processing of cocoa. Questionnaire method of data collection and direct interview were used on cocoa farm households in the study area. A combination of various analytical tools was used for the analysis which included descriptive statistics, principal component analysis (PCA) and Tobit model (TM). The PCA tool was used to derive an index of vulnerability to climate change based on farmers' responses relating to experience of seedling mortality due to drought. This method which is similar to Ordinary Least Square (OLS) regression ensures that an index of vulnerability is computed from all the climatic variables. The TM, on other hand, was used to estimate the responsiveness of yield of cocoa crops under the study to changes in climatic variables. The positive part of this study is that relative humidity was observed as one of the climatic variables possibly due to the aspect of the seed vulnerability in the study.

Factors that influence the supply and demand of cocoa produced were identified and researched into by Kareem et al, (2010). These variables included climate, micro-economic policy, global trading environment, developmental assistance among others. The factors were grouped into: climatic, price, and population changes for cocoa produce demand; and population, weather, and level of mechanization, for supply. Structured questionnaire items were prepared and administered among the Nigerian cocoa farmers, agro-allied industries, and research institutes in identified 13 states where cocoa produce are abundant. The states covered were Ondo, Osun, Edo-Ekiti, Cross-Rivers, Ogun, Lagos, Delta, Rivers, Anambra, Adamawa, and Oyo. The data obtained were subjected to multiple linear regression analysis using Statistical Package for Social Sciences (SPSS) for Window R^2 from which multiple regressing model parameters were estimated.

The flaws in these studies are that they are localized in scope with maximum length among them covering a period of ten years on one hand, and a year each respectively in the others, which by definition do not adequately reflect the effects of climate change on perennial tree crops like cocoa. For example, which year's climatic impact is being assessed since the impact of climate change on tree crops may not be instantaneous but may have lag effects (see, for example, Guan, 2006).

Studies on the general circulation model and cocoa physiological simulation model have also been observed in the methodological literature. For example, a country study on the vulnerability and adaptation of climate change on cocoa under the Netherlands climate change studies assessment program was carried out by Anim-Kwapong *et al*, (2004). They used climate change (temperature and rainfall) scenarios for the semi-deciduous forest and evergreen rainforest zones of Ghana constructed using process-based methods that rely on the General Circulation Models (GCM) in conjunction with Simple Climate Models (SCM). In the absence of CASE2 (CAcao Simulation Engine 2), a process-oriented computer model, which is a physiological model that simulates cocoa growth and yield for different weather and soil conditions and cropping systems, multiple regression were used as surrogate to analyze impact of climate change on cocoa production. This study is also limited by coverage and period covered.

The SUCROS-Cocoa model, on the other hand, is a physiological simulation model for cocoa that calculates growth and production of cocoa plantations, with or without water limitation. SUCROS-Cocoa is largely based on the SUCROS

(Gbetibouo, 2009) and INTERCOM (Galdeano-Go´mez, 2010) models. SUCROS models are physiological crop growth simulation models that calculate leaf-based light interception and photosynthesis, maintenance respiration, biomass growth and crop production in time, and have been applied mainly for annual crops. The INTERCOM model is derived from SUCROS and produces similar output, but for situations with several competing species: multiple crops, crops and weeds, crops and shade trees. The theoretical background on these models cited in (Gbetibouo, 2009; Galdeano-Go´mez, 2010 and a review in Costino, 2008).

On the use of the correlation analysis method, Lawal and Emaku (2007) evaluated the effect of climate changes on cocoa production in Nigeria. Rainfall, temperature and relative humidity were evaluated on cocoa yield and black pot disease incidence over 20 years. These variables were subjected to regression and analysis of variance (ANOVA) to establish the type and strength of relationship and effect of the parameters on yield and black pot disease incidence (F-test). The interest of the study was more on establishing correlation and the strength of these variables in determining yield.

FRAMEWORK AND MODEL SPECIFICATION

The theoretical framework leans on the crop yield response theory and uses transcendental logarithms (translog) function which descends from the flexible functional form of the production theory. The crop yield response theory allows for weather influence upon crops in agricultural production analysis. The proponents, Lang (1920), Koppen (1918), Martonne (1926), Angstrom (1936) and Thornthwaite (1948) combine precipitation and temperature into composite aridity indexes. Oury (1965) consolidated the ideas of the earlier studies and used a Cobb-Douglas specification where weather variables were considered as additional input into the production process. Recent studies (see, Lau, 1986; Sauer et al, 2004) however have widely used the translog functional form for crop yield response analysis.

We specify our model as:

$$Y = f(x_i) \qquad (4)$$

Where Y is the output of cocoa from the West African Region and x_i are the vector of inputs comprising both growth and facilitating inputs. In specific terms, the x_i is given as:

$$Y_t = f(L_t, K_t, T_t, P_t) \qquad (5)$$

Where Y, L, K, T and P are cocoa output, Labour input, Capital input and exogenous temperature input and exogenous precipitation input respectively.

The time series aggregate translog function can be derived as:

$$InY_{it} = InA + \alpha_T{}^* In(L_t) + \alpha_K{}^* In(K_t) + \alpha_T{}^* In(T_t) + \alpha_p{}^* In(P_t) + \beta_{LL}{}^* In(L_t)^* In(L_t) +$$

$$\beta_{KK}{}^{*} In(K_t)^{*} In(K_t) + \beta_{TT}{}^{*} In(T_t)^{*} In(T_t) + \beta_{PP}{}^{*} In(P_t)^{*} In(P_t) + \gamma_{LK}{}^{*} In(L_t)^{*} In(K_t) + \gamma_{LT}{}^{*} In(L_t)^{*} In(T_t) +$$

$$\gamma_{LP}{}^{*} In(L_t)^{*} In(P_t) + \gamma_{KT}{}^{*} In(K_t)^{*} In(T_t) + \theta_{KP}{}^{*} In(K_t)^{*} In(P_t) + \theta_{KL}{}^{*} In(K_t)^{*} In(L_t) +$$

$$\psi_{TL}{}^{*} In(T_t)^{*} In(L_t) + \psi_{TK}{}^{*} In(T_t)^{*} In(K_t) + \psi_{TP}{}^{*} In(T_t)^{*} In(P_t) + \psi_{PL}{}^{*} In(P_t)^{*} In(L_t) +$$

$$\eta_{PK}{}^{*} In(P_t)^{*} In(K_t) + \eta_{PT}{}^{*} In(P_t)^{*} In(T_t) = f(L_t, K_t, T_t, P_t) \tag{6}$$

By invoking the six (6) cross-equation symmetry conditions on (6) as:

$$\gamma_{LK} = \theta_{KL}; \gamma_{LT} = \gamma_{TL}; \gamma_{LP} = \gamma_{PL}; \gamma_{KT} = \psi_{TK};$$
$$\theta_{KP} = \eta_{PK}; \psi_{TP} = \eta_{PT}$$

Hence, equation (6) reduces from 20 variables to 14 variables as:

$$InY_t = InA + \alpha_L{}^{*} In(L_t) + \alpha_K{}^{*} In(K_t) + \alpha_T{}^{*} In(T_t) + \alpha_P{}^{*} In(P_t) + \beta_{LL}{}^{*} In(L_t)^{*} In(L_t) +$$

$$\beta_{KK}{}^{*}(K_t)^{*} In(K_t) + \beta_{TT}{}^{*} In(T_t)^{*} In(T_t) + \beta_{PP}{}^{*} In(P_t)^{*} In(P_t) + \gamma_{LK}{}^{*} In(L_t)^{*} In(K_t) + \gamma_{LT}{}^{*} In(L_t)^{*} In(T_t) +$$

$$\gamma_{LP}{}^{*} In(L_t)^{*} In(P_t) + \gamma_{KT}{}^{*} In(K_t)^{*} In(T_t) + \theta_{KP}{}^{*} In(K_t)^{*} In(P_t) + \theta_{TP}{}^{*} In(T_t)^{*} In(P_t) \tag{7}$$

By simplifying and re-arranging (7) yields equation (8) as:

$$\begin{aligned} InY_t = {} & InA + \alpha_L InL_t + \alpha_K InK_t + \alpha_T InT_t + \alpha_P InP_t + \tfrac{1}{2}\beta_{LL} In(L_t)^2 + \tfrac{1}{2}\beta_{KK} In(K_t)^2 + \tfrac{1}{2}\beta_{TT} In(T_t)^2 + \tfrac{1}{2}\beta_{PP} In(P_t)^2 + \\ & \gamma_{LK} InL_t InK_t + \gamma_{LT} InL_t InT_t + \gamma_{LP} InL_t InP_t + \gamma_{KT} InK_t InT_t + \theta_{KP} InK_t InP_t + \theta_{TP} InT_t InP_t \end{aligned} \tag{8}$$

The agronomic literature (see e.g. Guan, 2006) and Dell et al 2010) points out that perennial tree crops (like cocoa) may not have instantaneous temperature and precipitation effects. Rather, the impact of climatic variables on tree crops usually has growth effect. Unlike arable crops, weather shocks will only have a level effect such that as soon as the weather shock reduces to normal, crop yield is restored. Climate effects slowly play more on growth of cocoa and therefore on its output. Due to this, the study incorporates a more standard distributed lags on the climate variables. As a result, employing a dynamic translog equation by introducing p lags on the climatic variables in equation (8) leads to equation (9):

$$InY_t = InA + \alpha_L InL_t + \alpha_K InK_t + \alpha_T InT_{t-p} + \alpha_P InP_{t-p} + \tfrac{1}{2}\beta_{LL} In(L_t)^2 + \tfrac{1}{2}\beta_{KK} In(K_t)^2 + \tfrac{1}{2}\beta_{tt} In(T_{t-p})^2 + \tfrac{1}{2}\beta_{PP} In(P_{t-p})^2 +$$

$$\gamma_{LK} InL_t InK_t + \gamma_{LT} InL_t InT_{t-p} + \gamma_{LP} InL_t InP_{t-p} + \gamma_{KT} InK_t InT_{t-p} + \theta_{KP} InK_t InP_{t-p} + \theta_{TP} InT_{t-p} InP_{t-p} + \varepsilon_t \tag{9}$$

Procedure and Technique

Since the objective of this time series estimation is to ascertain the long run relationship between the dependent and the independent variables, cointegration test was first applied on the model. The application of the cointegration test for cocoa output requires the examination of time series properties of the data. Seasonal characteristics of the data are analyzed by using autocorrelation and partial autocorrelation functions. All the variables are included in the same order. The seasonal unit root hypothesis is tested by Johansen method via E-views statistics and here the use of Philips-Perron test statistics and the ADF method developed by Dickey –Fuller were used.

Cointegration means that long-run equilibrium relationship exists among the non-stationary variables. However, cointegrating regression considers only the long-run property of the model, and does not explicitly deal with the short-run dynamics. A good time series modeling should clearly describe both short-run dynamics and the long-run equilibrium simultaneously. Granger and Newbold (1977), and Granger and Engle (1983) have all shown that the existence of cointegration is an adequate condition for the incorporation of an Error Correction Term (ECT). The inclusion of ECT in a model ensures that the long run relationship is preserved. The equation for the ECM was then specified as:

$$InY_t = InA + \Psi(lp)\alpha_L InL_t + \Psi(lp)\alpha_K InK_t + \Psi(lp)\alpha_T InT_{t-p} + \Psi(lp)\alpha_P InP_{t-p} + \Psi(lp)\tfrac{1}{2}\beta_{LL} In(L_t)^2 + \Psi(lp)\tfrac{1}{2}\beta_{KK} In(K_t)^2 + \Psi(lp)\tfrac{1}{2}\beta_{tt} In(T_{t-p})^2 + \Psi(lp)\tfrac{1}{2}\beta_{PP} In(P_{t-p})^2 + \Psi(lp)\gamma_{LK} InL_t InK_t + \Psi(lp)\gamma_{LT} InL_t InT_{t-p} + \Psi(lp)\gamma_{LP} InL_t InP_{t-p} + \Psi(lp)\gamma_{KT} InK_t InT_{t-p} + \Psi(lp)\theta_{KP} InK_t InP_{t-p} + \Psi(lp)\theta_{TP} InT_{t-p} InP_{t-p} + \varepsilon_t \qquad (10)$$

Data and Sources.

Temperature and Precipitation data were sourced from the FAOSTAT for selected cocoa producing countries in West Africa. In this respect, both yearly mean temperature and precipitation were used for the analysis. Because the effect of climate change is about extreme, maximum and minimum temperature and precipitation were respectively sourced as well. This study used the annual production data on cocoa beans in metric tonnes. Fertilizer import data were also sourced from FAOSTAT data base. Data on active population in agriculture as a proxy for Labour input was sourced from the African Development Indicators (ADI).

Presentation and Analysis of Results.

This section presents the unit root and cointeration test of the Engle-Granger error correction approach. This is then followed by the ECM results. The analysis occupies the final part of this section.

Unit Root Tests

Standard inference procedures do not apply to regressions which contain an integrated dependent variable or integrated regressors. Therefore, it is important to check whether a series is stationary or not before using it in a regression. In this study, the augmented Dickey-Fuller test (1979) and Phillips-Peron test (1998) with a truncated lag of 11 was explored. The two tests were performed, because they make different assumptions about the residuals from the auxiliary regression. Whereas Dickey-Fuller (1979) class of tests assumes that the residuals from the auxiliary regression are white noise, the Philips Perron (1998) makes no assumption about these residuals. The report describes the *t*-statistics which is compared to the critical values for decision making on the hypotheses and the *p* values (in parentheses).

Both ADF and PP, though differed slightly in terms of figures, they all offered the same conclusion (significance levels). The results indicated that all the variables were not significant at levels, because their respective *t*-statistics were larger than the critical values at the various percentage levels. However, the results of the first difference were all stationary and integrated of the same order one (I(1)).

Cointegration Tests

Engle *et al* (1987) pointed out that a linear combination of two or more non-stationary series may be stationary. If such a stationary linear combination exists, the non-stationary time series are said to be cointegrated. The stationary linear combination is called the cointegrating equation and may be interpreted as a long-run equilibrium relationship among the variables. This study used the Engle-Granger Approach.

In the Engle Granger's approach, the variables as subjected to unit root tests to determine their stationarity were first estimated and the residuals tested for unit root as well. All variables were differenced to stationarity prior to the estimation (as reported above). Satisfied with the results, they were converted to ECM series and used for the encompassing model (over-parameterized model) from which the parsimonious one was ascertained for interpretation. In this case, along with the contemporaneous values of the explanatory variables, their lag and lead values were added as separate variables so as to ensure a movement from "General-to-specific".

Table 2: Results of the Engle Granger Cointegration Tests for the selected Countries

Country	Mean Climatic Values		Maximum Climatic Values	
	ADF	PP	ADF	PP
Nigeria	-4.036440 (0.0003)	-4.036440 (0.0032)	-3.915799 (0.0044)	-3.772169 (0.0065)
Ghana	-4.045129 (0.0031)	-3.981518 (0.0037)	-4.063627 (0.0029)	-3.984036 (0.0036)
Cote D'Ivoire	-5.208639 (0.0001)	-4.943327 (0.0002)	-4.637150 (0.0006)	-4.614954 (0.0006)

Source: Authors estimation result (2011). Note: All variables were significant at the 1 percent level. Maximum lag selected by SIC is 9.

RESULTS AND ANALYSIS OF THE ENGLE-GRANGER ERROR CORRECTION MODEL (ECM)

The ECM method resulted in different speed of adjustment for the selected countries and also accounted for the size, signs and significance of the lags of these climatic variables in the respective countries. A cogent analysis of the two estimations utilizing both data sets is as follows:

The variables that emerged in the ECM parsimonious estimation was quite the same for the two data sets but differed from country to country. In Nigeria the speed of adjustment was -0.67. This suggested that, using the mean values for Nigeria's case, deviations from equilibrium are corrected at about 67% per annum. With the maximum data set, the ECM term was 57%. This was a decline if compared to the minimum data set results. The inference in this case is a clear indication that as temperature rises with precipitation declining, it takes a longer period for equilibrium to be restored, holding all other factors constant. The other important comparative results in Nigeria's case were that, while the lags of temperature was significant with the use of the two data sets precipitation was significant for only the maximum data set. That is, a year lag of temperature was -0.396 and -0.846 for mean and maximum data sets, and a year lag of precipitation coefficients were 0.561 and 0.059 respectively.

Table 3: Results of the ECM on Nigeria.

Variable	**Mean Climatic Values**		**Maximum Climatic Values**		
	Coefficient	**Prob.**	**Variables**	**Coefficient**	**Prob.**
CONSTANT	-0.498670	0.0000	CONSTANT (C)	-0.380923	0.0000
D(LNK)	-0.071734	0.1054	D(LNL)	0.492948	0.0000
D(LNL)	0.546340	0.0000	D(LNK)	0.058929	0.0001
D(LNP)	0.561576	0.0000	D(LNKLNT)	0.257980	0.0034
D(LNY)	0.628493	0.0001	D(LNLLNP(-1))	0.160156	0.0028
D(LNLLNP)	0.383494	0.0000	D(LNLLNP)	0.219128	0.0001
D(LNKLNT)	0.417006	0.0000	D(LNP)	0.059080	0.6286
D(LNT)	-0.39678	0.0002	D(LNT)	-0.846517	0.0037
D(LNK(-1))	-0.223810	0.0000	ECM(-1)	-0.568292	0.0000
D(LNLLNP(-1))	0.288088	0.0287			
ECM(-1)	-0.671087	0.0000			
R^2 : ***Adj R^2 :*** ***S.E*** ***SS resid:*** ***Log likelihood:*** ***DW stat:*** ***Prob (F-stat):***	0.828643 0.758831 0.037896 0.038776 79.47520 1.826959 0.000000		***R^2 :*** ***Adj R^2 :*** ***S.E*** ***SS resid:*** ***Log likelihood:*** ***DW stat:*** ***Prob (F-stat***	0.695185 0.613902 0.047950 0.068975 68.24408 1.720557 0.000005	

Source: Author's Estimations (2011).

This result is akin to that of the panel study by the same authors (the impact of climate change in West Africa) in terms of the sequence of trend and size of the coefficients. The deduction from Nigeria's case is that precipitation had not provided the needed support for cocoa production over the study period but the trend of the results shows precipitation is improving. This is counter factual to the forecast offered by the scientific reports. Temperature, however, revealed a larger negative coefficient professing a dreary future for the cocoa industry in Nigeria. In conclusion, since a blend of the two in their rightful proportions are very important for cocoa production as indicated in the agronomic literature (see e.g. Lawal and Emaku, 2007), it would be convenient to state that Nigeria's cocoa industry faces blurred future.

The ECM results for Ghana using the mean values suggested that deviations from equilibrium are restored by 43% annually. This figure is quite lower than the Nigeria's case, implying that the speed of adjustment is higher in Nigeria's case than for

Ghana. The ECM using the maximum data set for Ghana is the same as that of Nigeria's case. The term suggests that past deviations from equilibrium are restored by 57% annually. By contrasting this result with Nigeria's case, it is clear that whereas the speed of adjustment increases with the maximum value estimation results for Ghana it is the opposite of Nigeria. This connotes that as climate situation worsens Ghana would have more capacity or mechanism to forestall faster to equilibrium after climate shocks than Nigeria. In terms of the lag effects utilizing the mean data set, it is clear that, whereas one year lag of temperature was significant with coefficient of 0.517, the second year lag was insignificant with -0.707. The sign is positive and lower than one year lag.

Table 4: Results of the ECM on Ghana.

Variable	**Mean Climatic Values**		**Maximum Climatic Values**		
	Coefficient	**Prob.**	**Variables**	**Coefficient**	**Prob.**
CONSTANT (C)	-0.112286	0.0147	CONSTANT (C)	-0.315404	0.0071
D(LNT)	-0.1890063	0.3041	D(LNL)	0.1400089	0.0299
D(LNLLNP)	0.746263	0.0234	D(LNT)	-0.776000	0.0483
D(LNKLNT)	-0.13788	0.1321	D(LNTYR3)	0.6843083	0.0496
D(LNK(-1))	0.381121	0.0300	D(LNK(-1))	0.5444510	0.0145
D(LNT(-2))	-0.707991	0.3164	D(LNK(-2)	0.2637480	0.0306
D(LNT(-1))	0.517678	0.0297	D(LNP(-1))	0.2081780	0.0000
D(LNP(-2))	0.031330	0.2010	D(LNP(-2))	0.2724561	0.0001
D(LNTYR3(-1))	-0.053404	0.1223	D(LNTYR3(-1))	0.8678210	0.0069
D(LNP(-1))	0.048149	0.0756	D(LNTYR3(-2))	0.3249490	0.0350
D(LNTYR3(-2))	-0.538520	0.0343	D(LNLLNP(-1))	-0.2937562	0.0000
D(LNLLNP(-1))	0.236485	0.2265	D(LNLLNP(-2))	-0.3845890	0.0000
ECM(-1)	-0.434610	0.0089	D(LNKLNT(-1))	-0.1089484	0.0144
-	-	-	D(LNKLNT(-2))	-0.892666	0.0301
-	-	-	D(LNPYR1(-2))	0.517662	0.0487
-	-	-	ECM(-1)	-0.712734	0.0000
R^2:	0.510098		R^2:	0.821049	
Adj R^2:	0.176074		Adj R^2:	0.684705	
S.E	0.070481		S.E	0.043600	
SS resid:	0.109287		SS resid:	0.039921	
Log likelihood:	57.25618		Log likelihood:	76.39090	
DW stat:	1.830103		DW stat:	1.554967	
Prob (F-stat):	0.0178630		Prob (F-stat	0.000103	

Source: Author's Estimations (2011).

The parsimonious result of the maximum data set reports significant coefficients of -0.684, -0.776 for a year lag and three years' lag of temperature respectively. Precipitation for lags one to three was also all significant. The understanding offered in this result is that the nature of impacts of climatic variables in the sub-region are similar but with some marginal differences.

The error correction term in Cote D'Ivoire's case, unlike the mean data set results for Ghana and Nigeria, is very high and negative as was expected. The speed of adjustment value implied that about 83% of preceding year's disequilibrium was restored in the current year. The error correction mechanism in Cote D'Ivoire's case using the maximum data set, contrary to the mean data set, showed lower speed of adjustment. This figure was -0.390 implying that 39% of previous year's shocks are corrected for in the current year. This result follow similar outcome to the Nigeria's case, but is direct opposite to Ghana's case. Cote D'Ivoire and Nigeria's case proposes that when the mean values are used, deviations from equilibrium are quickly restored, but the restoration process in using the maximum values is slower. Ghana's case is rather the opposite, implying that with the use of the maximum values, the speed of adjustment to equilibrium after deviation is faster than using the mean values. This striking result portrayed that, given the data set each country in the sub-region has its level of adjustment towards equilibrium after climate distortions. In other words, the carrying capacity of each country determines the speed of adjustment when there is a climate shock (torrid season) on cocoa production.

In terms of the participating climatic variables, unlike Ghana's mean case where temperature was not significant, Cote D'Ivoire had temperature to be significant at both the use of mean and maximum climatic data sets. Incidentally, precipitation was not part of the parsimonious model. However, one year lag of precipitation was significant and with a positive coefficient. The interaction and lag effects of the climatic variables were also discernible in the results of Cote D'Ivoire. For example, a three year lag of temperature in Cote D'Ivoire's case still lingered over to the current year. Present period and the preceding two years capital interaction with temperature had substantial positive effects on cocoa output in Cote D'Ivoire. Also, two years lag of labour; capital and temperature all had various positive impacts on cocoa output in Cote D'Ivoire in various degrees.

Table 5: Results of the ECM on Cote D'Ivoire.

Variable	**Mean Climatic Values**		**Maximum Climatic Values**		
	Coefficient	**Prob.**	**Variables**	**Coefficient**	**Prob.**
CONSTANT (C)	0.029035	0.0612	CONSTANT (C)	0.022802	0.0403
D(LNL)	0.647971	0.0049	D(LNK)	0.499450	0.0031
D(LNT)	-0.4684863	0.0000	D(LNT)	-0.455075	0.0000
D(LNTYR3)	-0.3290531	0.0000	D(LNTYR3)	-0.390685	0.0000
D(LNKLNT)	0.0367590	0.0009	D(LNK(-2))	0.585045	0.0026
D(LNY(-1))	0.4874360	0.0384	D(LNT(-2))	-0.806118	0.0001
D(LNL(-2))	0.7305449	0.0042	D(LNP(-1))	0.107935	0.0012
D(LNK(-2))	0.6640469	0.0003	D(LNTYR3(-2))	-0.574692	0.0001
D(LNT(-2))	-0.7783509	0.0000	D(LNKLNT(-2))	0.484976	0.0026
D(LNP(-1))	0.172687	0.0000	ECM(-1)	-0.390203	0.0386
D(LNTYR3(-1))	-0.1915682	0.0079	-	-	-
D(LNTYR3(-2))	-0.7094475	0.0000	-	-	-
D(LNKLNT(-2))	0.464068	0.0003	-	-	-
D(LNPYR1(-1))	0.040287	0.0043	-	-	-
ECM(-1)	-0.828318	0.0001	-	-	-
-	-	-	-	-	-
R^2:	0.947636		R^2:	.900434	
Adj R^2:	0.915762		Adj R^2:	0.868431	
S.E	0.050636		S.E	0.063283	
SS resid:	0.058972		SS resid:	0.112131	
Log likelihood:	68.97749		Log likelihood:	56.76809	
DW stat:	2.142940		DW stat:	2.112940	
Prob (F-stat):			Prob (F-stat		

Source: Author's Estimations Results (2011).

CONCLUSION AND RECOMMENDATION

Climate change due to anthropogenic factors has led to new patterns of temperature and precipitation. These new patterns are projected to reduce agricultural yields including cocoa globally. The possibility that climate change could change the quantity of cocoa produced from the sub-region was therefore worth investigating and this formed the center piece of this study. Studies on the impact of climate change on agriculture have focused more on arable crops rendering cocoa studies inchoate in the literature. Even studies in the area of cocoa are rather limited in time frame, coverage and are inconclusive in the literature. Therefore, the study examined the impact of climate change on cocoa production in selected countries in West Africa.

The selected countries were Nigeria, Ghana and Cote D'Ivoire which jointly supply 67% of the World market cocoa. ECM was the method of analysis because it is robust to possible omitted variables.

The result shows that the two climatic variables, their lags and interaction with other leading variables such as labour and capital have various degrees of impact on cocoa output in the selected countries. The ECM showed different speed of adjustment to long run equilibrium. This ranged between 39% to 82% with the lowest recorded by Nigeria and the highest by Cote D'Ivoire. The implication of the ECM results indicates that the future of the cocoa industry in the sub-region depends on the impact of localized extreme climatic events that could occur and the adjustment capacity of these countries to long run equilibrium after climate shocks.

It is therefore recommended that the authorities in these countries should develop adaptation strategies that would fit into local climatic conditions. This could take the form of extension services to enhance the maintenance of cocoa shade that can contribute to buffering temperatures and also improve hydrological cycling. Establishment of irrigation systems in farms through the provision of infrastructure, education and training for cocoa farmers are also encouraged.

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