IMPACT OF CLIMATE CHANGE ON COCOA PRODUCTION IN WEST AFRICA

By

KENNETH OFORI-BOATENG

(Matriculation Number: 162525)
MA Economics, KNUST, Ghana
B.A (Hons) Economics & Law, KNUST, Ghana

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ABSTRACT

West Africa's supply of 70% of world cocoa output generates 2 billion US dollars annually and contributes substantially to the economic development of the region. Climate change has led to new patterns of temperature and precipitation which are projected to reduce agricultural yields, including cocoa production, globally. Studies on the impact of climate change have focused on arable crops with very little attention to cash crop like cocoa. This study, therefore, examined the current and future impact of climate change on cocoa production in West Africa from 1969 to 2009.

A transcendental logarithmic (translog) production function, based on the crop yield response framework, was tested using data drawn from eight cocoa producing countries, namely; Cote D'Ivoire, Ghana, Nigeria, Togo, Benin, Liberia, Sierra-Leone and Guinea. Panel regression techniques of fixed and random effects were used to determine the current impact of climate change on cocoa output. In order to ascertain the speed of adjustment to long-run equilibrium, the panel analysis was complemented with the Engle-Granger Error Correction Model (ECM). The future impact of climate change on cocoa output was analysed with an out-of-sample simulation for the sub-region. The simulation was based on plausible scenarios of various scientific reports including those of the Intergovernmental Panel on Climate Change (IPCC). Since crop yields are sensitive to weather extremes, the data used were the maximum values of temperature and precipitation alongside their mean values.

Precipitation positively affected cocoa production in the sub-region with an estimated coefficient of 0.77for the mean dataset and 0.52 for the maximum dataset. The impact of temperature on cocoa output was significant only under the extreme temperature condition. Specifically, while temperature had a negative impact on cocoa output with an estimated coefficient of -0.57 for the maximum dataset, the estimated coefficient for the mean dataset was -0.30. The ECM showed that the speed of adjustment to long-run equilibrium ranged from 39.0% to 57.0% and from 43.0% to 83.0% for the maximum and mean datasets respectively. The lowest speed of adjustment in the region was recorded by Nigeria while the highest was recorded by Cote D'Ivoire. Moreover, the simulation results showed that with the current trajectory of temperature increase of 0.02^{o}C per annum and precipitation decrease of 0.002mm per annum, cocoa output in the West African sub-region would reduce by 8.6% in the next ten years.

Extreme temperature adversely affected cocoa output in the West African Sub-region. The increasing temperature and declining precipitation trends would also reduce cocoa output in the future. These threaten the future of cocoa industry in the Sub-region. Therefore, it is crucial for the authorities to develop adaptation strategies for the cocoa industry. This should take the form of investment in irrigation infrastructure to enhance cocoa output in periods of low precipitation. Also, farmers need to be encouraged and resourced to maintain cocoa shade on their farms to buffer temperatures in order to improve cocoa yield.

Keywords: Climate change, Cocoa output, Translog, Panel data.

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CERTIFICATION

We certify that this thesis was carried out by Mr. Kenneth Ofori-Boateng in the Department of Economics, University of Ibadan.

………………………………………………………………………..

(Supervisor and chairman, thesis committee)

E. OLAWALE OGUNKOLA

B.Sc., M.Sc., Ph.D (Ibadan)

Professor of Economics, Department of Economics

University of Ibadan, Ibadan, Nigeria.

…………………………………………………………………………

T. Ademola Oyejide

B.Sc. (Ibadan), M.Sc. (London), M.A., Ph.D. (Princeton)

Member, thesis committee

Professor, Department of Economics,

University of Ibadan, Nigeria

………………………………………………………………………….

Olugboyega A. OYERANTI

B.Sc (Edu) (Sokoto), M.Sc., Ph.D (Ibadan)

Senior lecturer, Department of Economics,

University of Ibadan, Nigeria

DEDICATION

This work is dedicated to my lovely wife Mrs. Cynthia Ofori-Boateng, my son Caleb Ofori-Boateng and my entire family, who had to learn hard to cope with the fact that Daddy was schooling and therefore would not have enough time for some social gatherings.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Since the outset of industrialization, there have been large increases in the levels of greenhouse gas (GHG) emissions caused by human activities (known as "anthropogenic" GHGs), and as a result, their concentration in the atmosphere has also increased. In simplified terms, higher concentrations of greenhouse gases in the atmosphere cause the sun's heat (which would otherwise be radiated back into space) to be retained in the earth's atmosphere, thereby contributing to the greenhouse effect that causes global warming and climate change (UNEP-WTO, 2009).

Besides carbon dioxide, the major anthropogenic greenhouse gases are ozone, methane, nitrous oxide, halocarbons and other industrial gases (Forster, Ramaswam, Fahey, 2007). All of these gases naturally occur in the atmosphere, with the exception of industrial gases, such as halocarbons. Carbon dioxide emissions currently account for 77 percent of the anthropogenic, or "enhanced", greenhouse effect and mainly result from the burning of fossil fuels and from deforestation (Baumert and Pershing, 2005). Changes in agriculture and land use are the main causes of increased emissions of methane and nitrous oxide, with methane emissions accounting for 14 percent of the enhanced greenhouse effect. The remaining approximately 9 percent consists of nitrous oxide emissions, ozone emissions from vehicle exhaust fumes and other sources, and emissions of halocarbons and other gases from industrial processes (UNFCCC, 2008).

A brief overview of the scientific evidence on climate change and its impacts 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. The world is committed to further warming because of the inertia built already into the climate system and the delay between mitigation and outcome. The world for at least, the first half of the 21st Century has no option than adaptation to climate change (WDR, 2010). Advanced countries already recognize the importance of adaptation and many of them are heavily investing in development of climate defense infrastructures. National strategies are being drawn up to prepare for more extreme and less certain future weather patterns. For example, the United Kingdom spends close to $1.2 billion annually on flood defenses. In the Netherlands, people are investing in homes that can float on water. The Swiss Alpine Ski industry is investing in Artificial Snow-making machines (UNDP 2007/8).

Currently, developing countries see the urgency involved in adaptation to climate change. However, how they adapt, and the choices open to individuals, and governments, are determined by many factors. This is because the nature of the risks associated with climate change varies across regions and countries. Also important is the capacity to adapt, since defining that capacity involves the state of human development, technological capacities and financial resources (UNEP-WTO, 2009). The most sensitive sector to climate change is well known to be agriculture with the production drivers as temperature and precipitation (Christensen, 1986). Unfortunately these production drivers can hardly be controlled and therefore, makes climate change risks a major source of uncertainty in agriculture.

1.2. Statement of the problem

The literature on climate now generally agrees that anthropogenic forcing has been a major cause of the accelerating pace of climate change (IPCC, 2007a). The general consensus on anthropogenic forcing, and an increased scientific understanding of climate change, is that the result of improved analyses of temperature records, coupled with the use of new computer models to estimate variability and climate system responds to both natural and man-made causes. This increased understanding of climate processes has made it possible to incorporate more detailed information (for example on sea-ice dynamics, ocean heat transport and water vapour) into the climate models, which has resulted in a greater certainty that the links observed between warming and its impacts are reliable (IPCC, 2007a). Based on an assessment of thousands of peer-reviewed scientific publications, the IPCC (2007a) concluded that the warming of the climate system is "unequivocal", and that there is a very high level of confidence, defined as more than 90 percent likelihood, that the global average net effect of human activities is climate warming (UNEP-WTO report, 2009).

Scientific reports on global warming have indicated that the average global temperature has increased by around 0.7ºC (1.3º F) since the advent of the industrial era (See e.g. Asafu-Adjaye, 2008; UNDP, 2007/8). Evidence shows the trend is accelerating such that average temperature is rising at 0.2ºC every decade (UNDP, 2007/8). 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. This rise will be less significant in coastal and equatorial areas (+3°C) and highest in Western Sahara (+4°C). Africa's Mediterranean region is expected to experience a decrease in precipitations (-15 to -20 percent) during this century. These dry conditions would affect the northern boundary of the Sahara and the West African coast. There are very significant uncertainties about forecasts over West Africa. No formal conclusion was drawn on this region's rainfall based on the results of these models. It is worthy of mention that rainfall is the determining element in West Africa's agricultural production (ECOWAP, 2009).

According to Boko, Niang and Nyong (2007), crop yield in some African countries has been projected to drop by up to 50 per cent as early as by 2020, and net crop revenues could fall by as much as 90 per cent by 2100, with small scale farmers being the worst affected. Fischer, Shah, Tubiello and Velhuizen (2005) estimate that some countries, including Sudan, Nigeria, Somalia, Ethiopia, Zimbabwe, and Chad, could lose their cereal-production potential by 2080. In South Asia, cereal yields are projected to decrease up to 30 percent by 2050 (Cruz, *et al,* 2007), while generalized reductions in rice yields are projected by the 2020s in Latin America (Nyong, 2008).

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). The Millennium Project (2005), in its report entitled "Halving Hunger: it can be done", concludes that the frequency of natural disasters increases when climate changes, and the resulting increased vulnerability causes the populations to take less risks; this attitude results in a decrease in agricultural investments and production. ENDA Tiers Monde (2005) indicates that the potential consequences of climate change in West Africa include, among other things, the increase in surface area under crop to the detriment of forests, protected areas, marginal lands and pastures, the increase in the number of conflicts between farmers and livestock breeders, the amplification of the phenomenon of migration, the loss of incomes by individuals, hence public authorities and the exacerbation of food insecurity.

Cocoa is one of the major agricultural exports from West Africa. 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 6.70 percent respectively to the World Market (Lundstedt and Pärssinen 2009, ICCO, 2009). Other cocoa producing countries in West Africa include Togo, Benin, Guinea, Liberia and Sierra Leone (ICCO, 2009). Overall, the West African sub-region contributes a total of 70 percent of World Market Share of cocoa and yields considerable revenue to these economies. World production is in excess 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). This study contends that cocoa production and export is very vital to the GDP and therefore, economic performance of these cocoa producing economies in West Africa.

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 (Duguma, Gockowski and Bakala, 2010).

Cocoa production, like all other agricultural commodities, depends to a large extent on the interaction between comparative advantage, which is determined by climate and resource endowments as well as a wide ranging set of policies. Because climate change results in new patterns of temperature and precipitation, cocoa comparative advantage enjoyed by the West African economies is likely to change, setting up the possibility of changes in trade flows as producers respond to changing constraints and opportunities. As with any change in comparative advantage, unfettered international trade allows comparative advantage to be fully exploited.

Production trends of cocoa have been characterized by shifts from one country to another as major producer. It originated from Mexico to Central America in the sixteenth century, and then moved to the Caribbean in the seventeenth century. Venezuela took over in the eighteenth century and then to Ecuador and Sao Tomé in the nineteenth century. In the twentieth century Brazil, Ghana and Nigeria were the leaders in production followed by Côte D'Ivoire (Griffon, 1997). Several reasons including weather have been ascribed to the cause of these shifts in production (Konan, 1993). The next shift is unknown but the threatening climate change for the sub-region gives room for worry as it could expedite such move.

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? This study answers these empirical questions.

1.3 Objectives of the study

Arising from the above problem, the overall objective of the study is to examine the current and future impact of climate change on cocoa production of the producing economies in West Africa. The specific objectives of the study are to:

(i) determine the extent of current impact of climate change on cocoa production in West Africa; and

(ii) simulate the possible future changes in cocoa production due to climate change under various temperature and precipitation scenarios.

1.4 Justification for the research

Four major contributions are made in this study. First, the development literature has demonstrated severally on the impact of climate change and variability on agricultural production in tropical and temperate regions of the world (see Collier, 2008, 2008a; Cline, 2008, Jamet and Corfee-Morlot 2009; Reilly and Neil, 1993; Polsky, 2004). An examination of the myriad of literature on the impact of climate change on seasonal agricultural yields shows that the effects are negative for tropical regions and positive for temperate regions of the world. The trend is expected to increase but will be more severe with global temperature rise above the tipping point of 2ºC (UNEP-WTO, 2009). Temperature surges and decline in precipitation have been established to have serious implications for Sub-Sahara African countries due to their reliance on rain-fed agriculture (IPCC Report, 2007; Thornton and Herrero, 2010). Without urgent mitigation action, the world would be unable to avoid dangerous climate change. But even the most stringent mitigation will be insufficient to avoid major human development setbacks. The world is already committed to further warming because of the inertia built already into the climate system and the delay between mitigation and outcome. The world for at least, the first half of the 21st Century has no option than to adapt to climate change (WDR, 2010).Various reports and research conclusions have revealed that adaptation to climate change is necessary and it is a private good in which the benefits of severity accrue to only the specific country. Meaningful adaptation, however, requires more country and regional specific studies for appropriate recommendations (Shah, Fischer and Velthuizen, 2008). This Sub-regional specific study attempts to serve as part of the ongoing base line literature for the impact of climate change on cocoa production.

Second, studies on the impact of climate change on perennial tree crops like cocoa are not well formed in the literature because most studies have rather concentrated on the arable crops (see Kareem et al, 2010, Kaiser, 1993, Kapetanaki et al, 1997, Kumar et al 2001). Literature review on climate with regard to the impact of climate change on cocoa production in West Africa shows that key cocoa studies are more localized in scope thereby making it impossible to ascertain the general trend of the impact of climate change on cocoa production in the region. For example, Oyekale and Olowa (2009) focused on the effects of climate change on cocoa production and vulnerability assessment in Nigeria, Anim-kwapong and Frimpong (2005) looked at vulnerability of agriculture to climate change using cocoa as a case study in Ghana, Ajewole and Sadiq (2010) worked on effects of climate change on cocoa yield in Oyo state. Related studies have focused on the impact of climate change on cocoa diseases and fertilizer use in specific countries (see for example, Ogunlade and Aikpokpodion, 2009; Lawal and Emaku, 2007). The approach to all these studies have been of short term duration in nature, but this study using agronomic ideas believes that climate needs longer period to capture trends of impact. Climatic conditions are very crucial in the process of production, processing and export of cocoa beans. The cocoa-tree has a lifespan of 25 to 30 years and reaches its full development towards the age of 10 years (Duguma et al, 2010) so that any extreme climatic fluctuations results in stunted growth, the consequence of which can reduce expected yield over years. This study is a serious attempt at meaningfully contending with the problem involved.

Third, methodological studies on the impact of climate change on agriculture have revolved around the use of two main methods, namely; the Ricardian Method and the reduced form crop model (Asafu-Adjaye, 2008). The Ricardian method is a cross-sectional technique that measures the determinant of farm revenue. The reduced form crop model is a process-based model derived from summary statistical estimate based on the results of an agronomic model of crop growth coupled with a linear programming model of US farms (Mendelsohn and Neumann, 1999). Specific studies on cocoa, apart from the Ricardian approach have been dominated by questionnaire approach as well as correlation analysis. These methods which are laboratory (controlled) kind of experiment require the use of primary data from farm yields per acreage and limited in time frame, mostly a year. Recent studies by Dell, Jones and Olken (2008 and 2009) have used secondary macro level data in a panel study to assess the impact of climate change on several livelihoods with much concentration on export of primary products. However, their study did not focus on the production of perennial tree crops like cocoa. The present study following the ideas of Dell *et al.* (2009) uses secondary level time series data in a panel setting to ascertain the impact of climate change on cocoa production in West Africa. Unlike other studies, this study develops a blend of agronomic and economic model that uses flexible functional production function to determine the impact of climate change on cocoa production. This is a departure from the primary data level approach of assessing the impact of climate change on agricultural produce as a whole of which cocoa is of immense importance among these crops in West Africa. This method also departs from the seasonal level approach of assessing climate change.

Fourth, the empirical literature is inconclusive as to whether temperature or precipitation is significant for analyzing the impact of climate change on agricultural produce as a whole. Several studies and reports have concluded that temperature is an appropriate variable for capturing the effects of climate change on crop yields in the temperate regions and precipitation for tropical regions (Mendelsohn and Neumann. 1994, 2003; Kurukulasuriya & Mendelsohn 2006) (also see UNDP Report, 2007/8, UNEP-WTO Report, 2009, Stern Review, 2006). Kabubo-Mariara and Karanja (2007) found in Kenya that there is a non-linear relationship between temperature and crop revenue on the one hand, and between precipitation and crop revenue on the other. In the same region, a study in Kenya, Malawi and Ethiopia found that both temperature and precipitation are very relevant in explaining climatic impacts (IGAD/ICPAC, 2007). De (2009) identified both temperature and precipitation as significant in explaining the impact of climate change in Zimbabwe. On the other hand, Dell *et al* (2008) in their study across several countries of the world established that temperature has large, negative effects on economic growth, but only in poor countries. Unlike others, their results show that precipitation has no substantial effects on production and exports of primary products in both rich and poor countries. Jones and Olken (2010) find similar results. Ajewole *et al* (2010) in Ibadan concluded that whereas there is weak inverse correlation in rainfall, a positive weak correlation was established for temperature on cocoa yield. Since much attention has not been focused on perennial tree crops in the West African sub-region to ascertain the significance of these climatic variables, this study empirically tests this as well.

1.5 Scope of the study

The focus of this study is on the impact of climate change on cocoa production in West Africa. This study essentially examines how temperature and precipitation impact on the production of cocoa in Ghana, Côte D'Ivoire, Nigeria, Togo, Benin, Guinea, Liberia and Sierra-Leone. The choice of these countries is on the basis of the comparative advantage these countries currently enjoy mainly due to the favorable climatic conditions and the size these countries occupy in the world market. The study covers 41 years period (1969-2009), which is believed to be sufficient enough to examine climatic effects on cocoa production in West Africa.

1.6 Organization of the study

This study is organized into six main chapters. Chapter two contextualizes the study by dealing with the climatic conditions of West Africa, the economics of cocoa production and trends in the cocoa and the key climatic variables. Chapter three reviews the theoretical, methodological and empirical literature related to the impact of climate change on cocoa production. The theoretical framework and methodology is presented in Chapter four. Chapter five presents the results of the analytical part and a discussion of the results. Chapter six is the summary of major finding, conclusion and lessons for policy.

CHAPTER TWO

ECOSYSTEM AND ECONOMICS OF COCOA IN WEST AFRICA

The section discusses the natural conditions that serve as catalyst to cocoa production in the West African sub-region. Agronomic processes involved in cocoa production are succinctly explored to situate how a departure from the *status quo* could hamper growth of the crop. Economics of cocoa production comprises demand and supply of the commodity to the world market as well as policies governing cocoa production in the sub-region is also discussed in this chapter. Finally, trend and correlation analysis relating to climatic variables capable of influencing cocoa production are covered as well.

2.1 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. However, out of the region's wide range of agri-pastoral output of 236 million hectares of cultivable land, only 23 percent has been exploited (ECOWAS, WAEMU & EU, 2008).

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).

2.2. The economics of cocoa production in West Africa

This section discusses the production (supply) and demand of cocoa in the sub-region. In other words, this section of the study examines the rudiments of cocoa production and its market supply, and its demand at the World market. It is important to indicate that demand for cocoa is measured by total grindings of cocoa, and supply is measured by gross crop production of cocoa.

2.2.1 Cocoa production in West Africa

Cocoa, a tropical perennial tree crop, is the product of the fruit of the cocoa tree. In natural state, the cocoa tree grows to a height of about 10 meters, but usually pruned to a height of 6 to 7 meters in order to facilitate the plucking of cocoa pods. Its pods directly grow on the branches and main trunk of the tree. The cocoa pods, about 25 cm long, contain about 30 to 40 cocoa beans. Cocoa trees are trimmed every four to five years. Under these conditions, one can expect a yield of 2 tonnes/ha. In Côte D'Ivoire, if the tree is not affected by climatic shocks, the average output turn out to be around 300-400 kg/ha (Onyabinama, 2006). About fifty percent of the cocoa bean is a fat, known as cocoa butter, which is of great use in making confectionery (Kishore, 2010).

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 model profile of good cocoa soils are deep and characterized by well drained non-gravelly top soil over sandy clay loam layer which usually contains both iron oxide concretions and quartz gravels. This layer overlies sedentary mottled clay, which merges with the incompletely weathered parent material. The best soils in terms of high cocoa production tend to have an average pH 5.6-7.2 in 1:2.5 water: soil, C/N ratio between 10-12, organic carbon not less than 3%, base exchange capacity of 3-15 me/100g soil available P greater than 20ppm in the 0-5 cm and 15 ppm in 0-20 cm layer (using buffered 0.002N H_2SO_4 extractant), exchangeable K not less than 0.25 /100g soil, (Ca + Mg) about 8-13 me/100g soil and no aluminum in the exchange complex.

Soils carrying cocoa in West Africa are classified as follows: unsuitable, suitable and highly suitable (Anim-Kwapong et al, 2005).

It also needs a shelter from strong winds and direct rays of the Sun. High humidity of 70 to 100 percent are generally required. However, extreme rainfall can result in conditions leading to development of fungus attack on the pods. These conditions are found in the main high forest belt of Côte D'Ivoire, Ghana and major parts of West Africa, and in Brazil. Cocoa is a fairly adaptable crop and has been successfully grown in African countries though the tree is the native of central and South America (Audibert, Brun, Mathonnat and Henry, 2006).

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).

In the agricultural sector in general, it is clear that due to the constantly increasing pressure on available land (as a result of high population densities), fallow periods have significantly reduced, and at present rarely exceed six years (Onyabinama, 2006). As a general rule, fallow shorter than ten years does not allow the soil to adequately recover and thus, the quality of the soil decreases with more frequent exploitation (Ewes, 1978). The diminishing fertility status of the soil due to shorter fallow periods implies that the soil nutrients in cocoa plantation are being mined annually via cocoa harvest (Ogunlade et al., 2009). Wessel (1971) reported that there is a steady decline in almost all the nutrients with length of cultivation. Omotoso (1975) showed that a crop of 1000kg dry cocoa beans remove about 20KgN, 4kgP and 10kg K and where the method of harvesting (as in Nigeria) involves the removal of pod husks from the field, the amount of potassium removed increased more than fivefold.

Ogunlade and Aikokpodion (2006) reported that phosphorus is grossly inadequate for optimum cocoa yield in cocoa ecologies of Nigeria.

Application of fertilizer is inevitable for the replacement of soil nutrients that are being mined through cocoa pod harvest annually. Adequate use of fertilizer has been found to increase agricultural output (Ogunlade et al., 2009). According to Olson (1970), fertilizer could increase food production by at least 50 percent. Opeyemi, Fideli, Ademola and Phillips (2005) reported that an effective use of fertilizer on cocoa would help not only to improve yield, but also has the advantages of profitability, product quality and environmental protection. Fertilizer usage is therefore considered as a key factor in maximizing cocoa production.

Cocoa is continuously reaped throughout the year, since the seed cases do not ripen at the same time. In West Africa they are intensively collected most in the harvest seasons- December and June, together constituting a crop year. The cocoa fruits are cut down by hand, often using long machetes. Machines cannot be used, because it is not possible to harvest all beans at the same time. This means cocoa production is more labour intensive than capital intensive. The seeds are fermented on the ground for around seven days and dried for approximately three weeks, before they are packed in bags and exported (Lundstedt et al, 2009).

2.2.2 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 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.

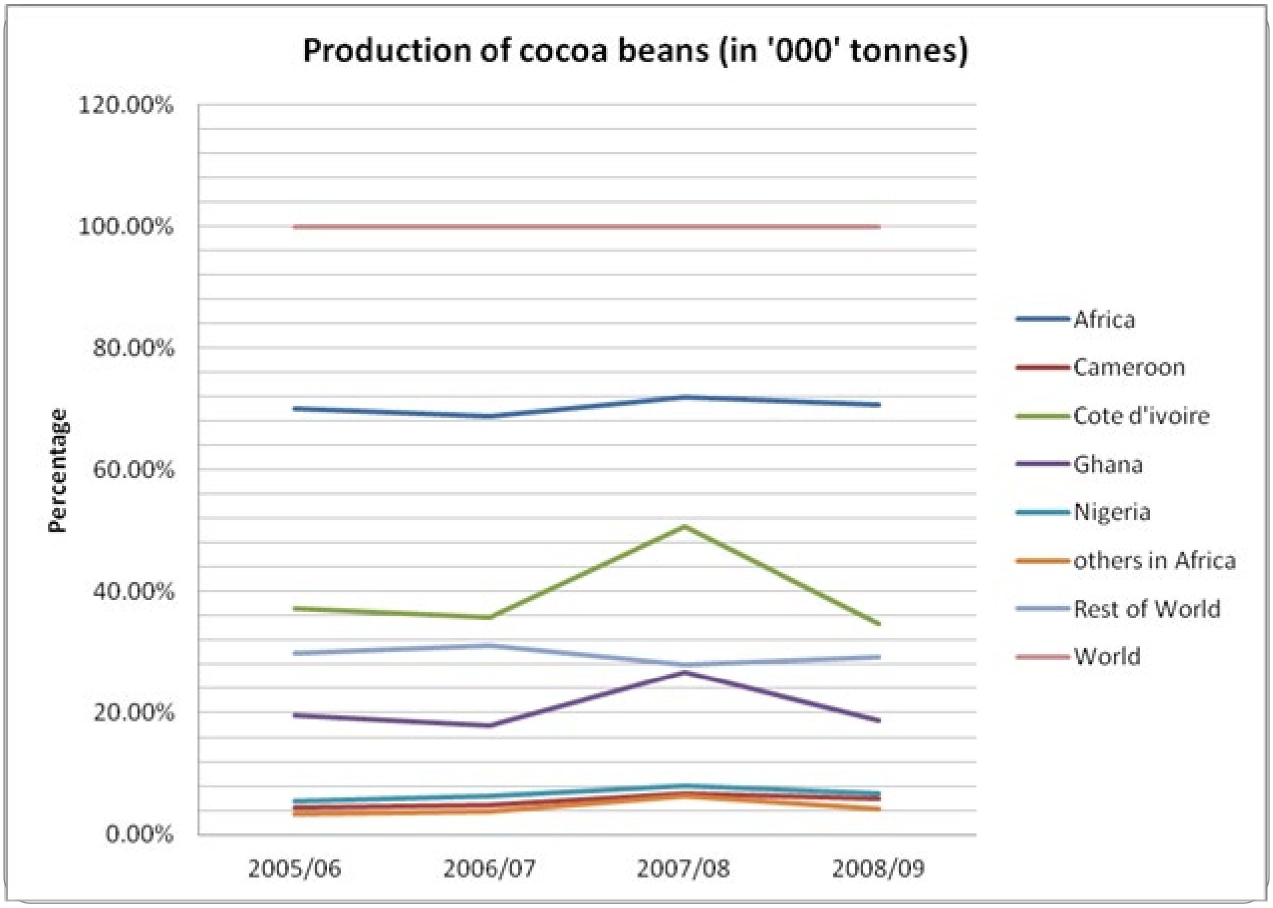

Figure 1: Production of Cocoa Beans by Country, 2005 - 2009, (in '000 tonnes)

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

The figure confirms that world production level of cocoa is nondeterministic as such sampled countries extend large exports of the product to meet the needed revenue for survival[1]. The trend of production exhibited in the Figures 1 and 2 show that production has been stochastic with major cocoa producing countries in SSA, namely, Cote D'Ivoire, Ghana, Nigeria and Cameroon. However, the share of Africa is still substantial compared to the world's total production. Figure 2, reports that, in total, Africa's contribution to the world cocoa market has remained fairly stable around 68.8% and 72% between 2005-2009 seasons. In 2007/08 season, Cote D'Ivoire, Ghana and Nigeria contributed about 86% of the total production of cocoa beans in the world. This figure fell to 61% in 2008/09 season due to torrid season as indicated by ICCO report (2009).

[1] With the exception of Nigeria whose major source of revenue is from the sale of crude oil, the rest of the sampled SSA countries depend on cocoa for the major foreign exchange.

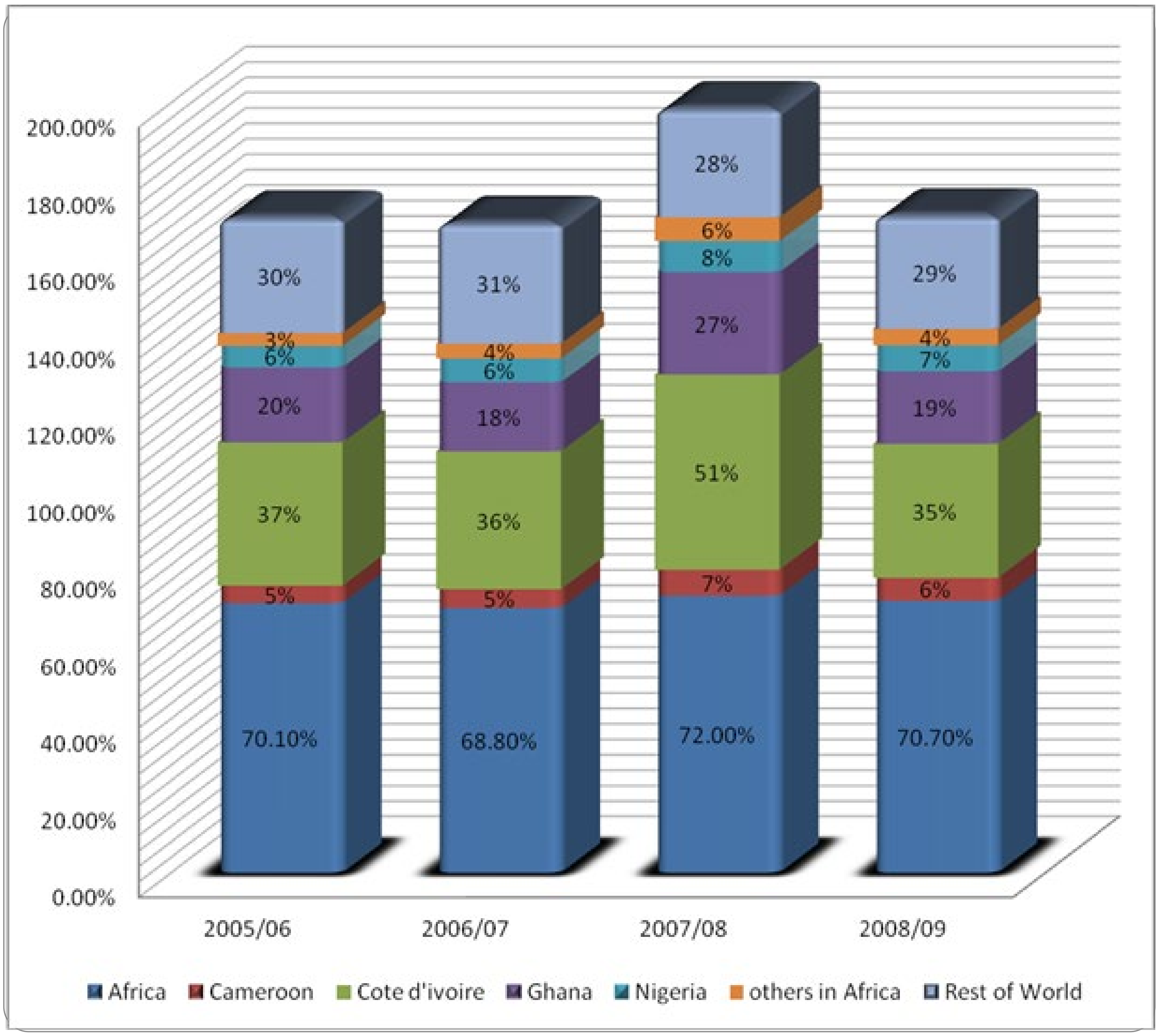

Figure 2: Percentage share of Africa in cocoa production from 2005/06 – 2008/09 seasons.

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

Table1 below shows the share (ranked) of twenty-five cocoa exporting countries in the world for the period 2005/6 season to 2008/9. The domination of production in two countries (Côte D'Ivoire and Ghana account for approximately 55 percent of world production) also means the weather, social and political situation or labour unrest can create great uncertainty in the supply of cocoa, which directly affects the price.

It is evident from Figure 1 and 2 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.

Table 1: Ranking of Twenty-Five Cocoa Exporting Countries

Country	2005/06	2006/07	2007/08	Average 3-year period 2005/06 – 2007/08	
	Tons			Tons	Shares
Cote D'Ivoire	1,349,639	1,200,154	1,191,377	1,247,057	38.75%
Ghana	648,687	702,784	673,403	674,958	20.98%
Indonesia	592,960	520,479	465,863	526,434	16.36%
Nigeria	207,215	207,075	232,715	215,668	6.70%
Cameroon	169,214	162,770	178,844	170,276	5.29%
Ecuador	108,678	110,308	115,264	111,417	3.46%
Togo	73,064	77,764	110,952	87,260	2.71%
Papua New Guinea	50,840	47,285	51,588	49,904	1.55%
Dominican Republic	31,629	42,999	34,106	36,245	1.13%
Guinea	18,880	17,620	17,070	17,857	0.55%
Peru	15,414	11,931	11,178	12,841	0.40%
Brazil	57,518	10,558	-32,512	11,855	0.37%
Venezuela	11,488	12,540	4,688	9,572	0.30%
Sierra Leone	4,736	8,910	14,838	9,495	0.30%
Uganda	8,270	8,880	8,450	8,533	0.27%
Tanzania	6,930	4,370	3,210	4,837	0.15%
Solomon Islands	4,378	4,075	4,426	4,293	0.13%
Haiti	3,460	3,900	4,660	4,007	0.12%
Madagascar	2,960	3,593	3,609	3,387	0.11%
Sao Tome & Principe	2,250	2,650	1,500	2,133	0.07%
Liberia	650	1,640	3,930	2,073	0.06%
Equatorial Guinea	1,870	2,260	1,990	2,040	0.06%
Vanuatu	1,790	1,450	1,260	1,500	0.05%
Nicaragua	892	750	1,128	923	0.03%
Congo, Dem Rep of	900	870	930	900	0.03%

Source: International Cocoa Organization (ICCO), 2008.

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 3 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.

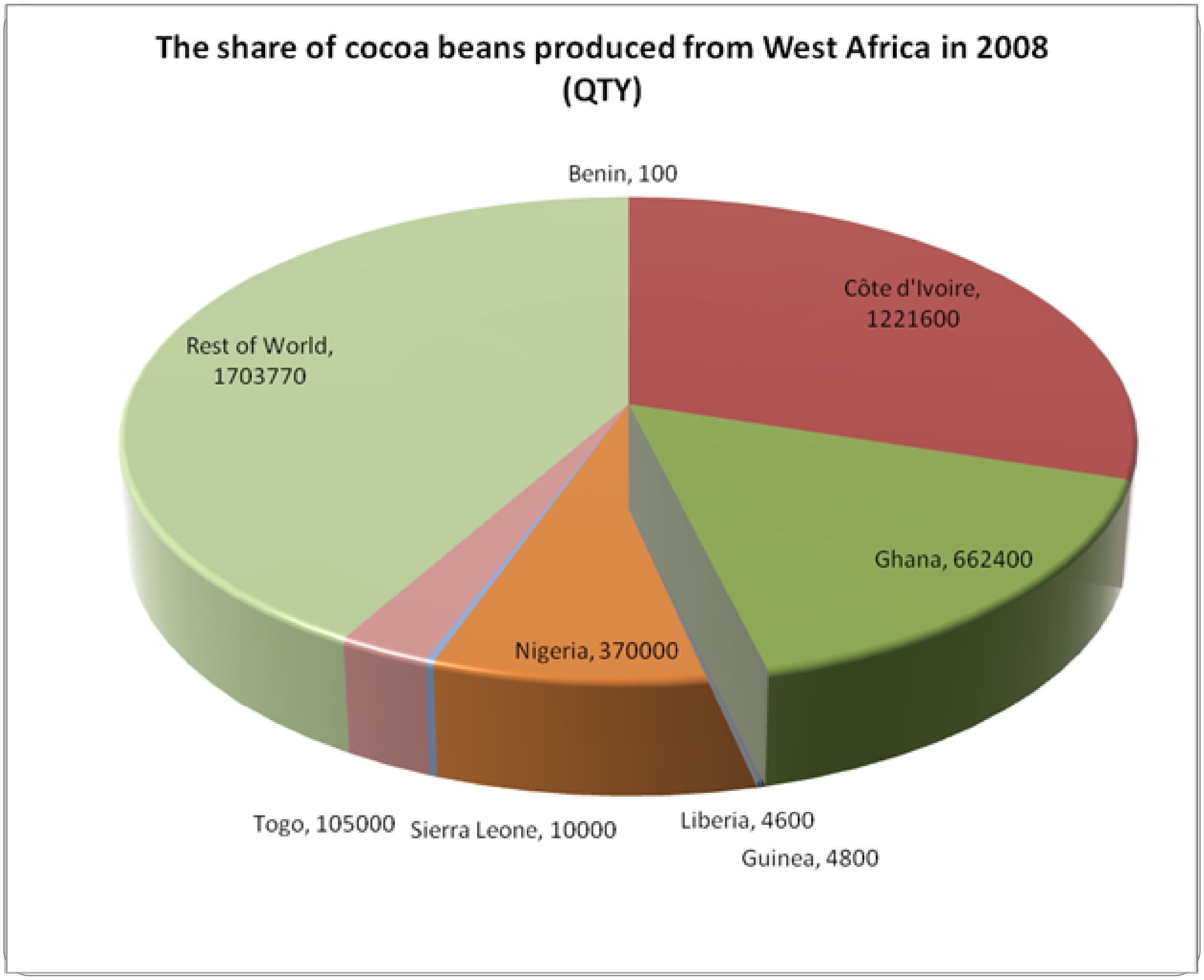

Figure 3: The share of cocoa beans produced from West Africa in 2008

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

In terms of exporting the beans, figure 4 below shows the share of top nine cocoa exporters in the world for the 2006/07 season. The indication is that the three main West African exporters in that season exported about 64% of the total cocoa beans of the world. In this season, Cote d'Ivoire's share dropped marginally to 39% while that of Ghana increased to 20%.

Considering that of world market supply of cocoa from SSA, Côte D'Ivoire, Ghana, Nigeria and Cameroon produce two-thirds and export three-quarters of total world cocoa production. Ghana was the primary producer of cocoa for most of the 20th century, and is today the second largest producer after Côte D'Ivoire. Indonesia is the third largest producer and Brazil, Malaysia and Ecuador are the other big producers. Figure 4 depicts the development of exports of cocoa by the three largest cocoa producing countries. The share of total exports supplied by Côte D'Ivoire decreased slightly during the epoch of the civil war, while the share supplied by Ghana increased from 15 to 19 percent. The amount supplied by Indonesia fairly remained constant, except for a substantial increase in the last crop year. Around 30 countries belong to the category labeled "rest of world" indicating that they are small suppliers of cocoa, even if their share has increased.

Figure 5 below shows the share of West Africa to the rest of the world. The export share of Cote D'Ivoire, Ghana, Nigeria and Togo has remained fairly constant over the review period. The last three seasons have shown some level of increases for Togo. Export of the cocoa beans from the remaining four cocoa producing countries has also been of the same size throughout 2000 to 2008 seasons. Together, the share of West Africa has generally improved over the 2000/2008 season.

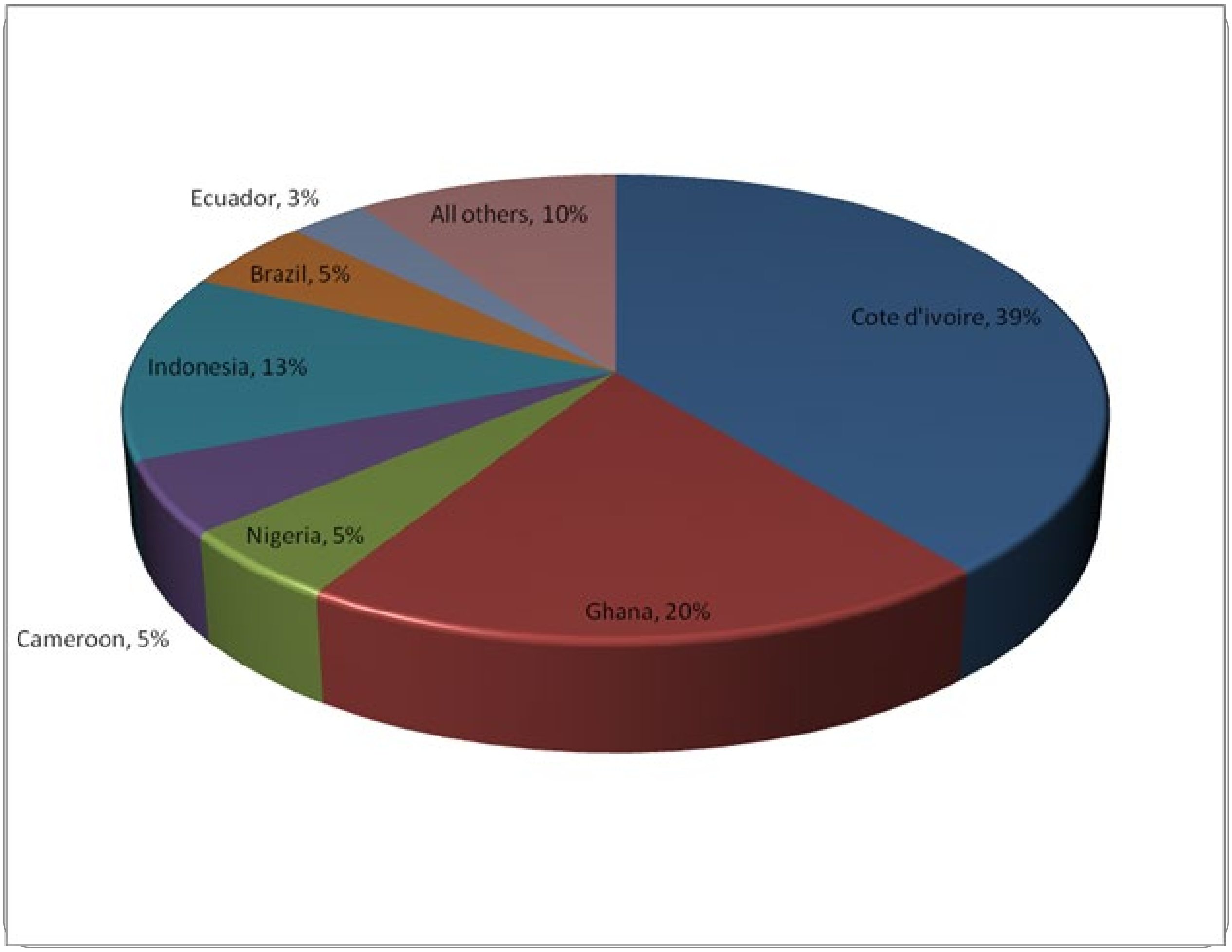

Figure 4: The Share of top nine world cocoa exporting countries.

Source: World Bank Cocoa Market Brief 2006, plotted by author, 2011.

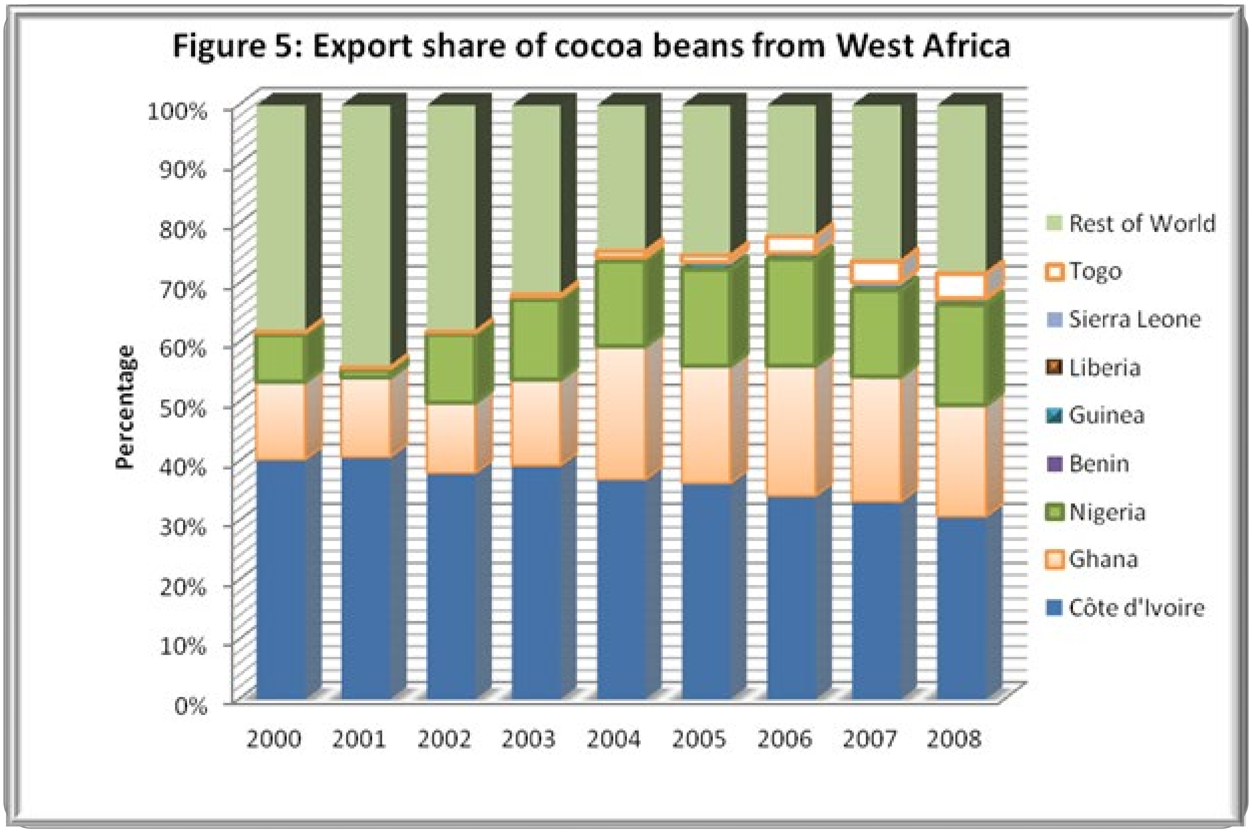

Figure 5: Export Share of Cocoa Beans from West Africa

Source: Data from FAO site and plotted based on author's calculations, 2011.

2.2.3 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[2] and final consumption[3] are considered better measures for estimating cocoa consumption on national basis (ICCO, 2009).

Table 2 reports the three approaches outlined above using data for the period 2005/06 to 2007/08, to represent the top 25 cocoa consuming countries. Most exports are directed to Europe which is both the biggest processor and consumer of cocoa. The prime customers of cocoa from the sub-region are the United States, U.K, Germany and Netherlands (ICCO, 2009). The other important importers are France, Spain, Belgium, Italy, and Japan. Cocoa is one of the main sources of foreign exchange to the sub-region. These countries account for about 46 percent of world imports. The U.S.A is the leading importer of cocoa products such as cocoa butter, liquor, and powder - accounting for 15 percent of world imports in recent years. China stands out as the leading cocoa consuming country amongst developing countries. Substitutes for cocoa butter in the manufacturing process, use of cocoa butter in non-food items such as cosmetics and changing popular tastes are also factors in the supply and demand cycle. The share of the main consuming countries in 2004/5 is represented by figure 4.

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.

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[2] Adding net import of cocoa products in bean is equivalent to grindings.
[3] Adding or subtracting net trade in both cocoa products and chocolate products in bean is equivalent to grindings.

Table 2: Ranking of Twenty-Five Cocoa Importing Countries in the world for the period 2005/6-2007/08 season.

Country*[i]	2005/06	2006/07	2007/08	Average 3-year period 2005/06 – 2007/08	
	Tonnes			Tonnes	Shares
United States	822,314	686,939	648,711	719,321	14.60%
Netherlands	581,459	653,451	681,693	638,868	12.97%
Germany	487,696	558,357	548,279	531,444	10.79%
France	388,153	421,822	379,239	396,405	8.05%
Malaysia	290,623	327,825	341,462	319,970	6.49%
United Kingdom	232,857	234,379	236,635	234,624	4.76%
Belgium/Luxembourg	199,058	224,761	218,852	214,224	4.35%
Russian Federation	163,637	176,700	197,720	179,352	3.64%
Spain	150,239	153,367	172,619	158,742	3.22%
Canada	159,783	135,164	136,967	143,971	2.92%
Italy	126,949	142,128	156,277	141,785	2.88%
Japan	112,823	145,512	88,403	115,579	2.35%
Poland	103,382	108,275	113,175	108,277	2.20%
Singapore	88,536	110,130	113,145	103,937	2.11%
China	77,942	72,532	101,671	84,048	1.71%
Switzerland	74,272	81,135	90,411	81,939	1.66%
Turkey	73,112	84,262	87,921	74,831	1.52%
Ukraine	63,408	74,344	86,741	53,428	1.08%
Australia	52,950	55,133	52,202	37,372	0.76%
Argentina	33,793	38,793	39,531	29,138	0.59%
Thailand	26,737	31,246	29,432	23,768	0.48%
Austria	20,119	26,576	24,609	20,572	0.42%
Philippines	18,549	21,260	21,906	19,904	0.40%
Mexico	19,229	15,434	25,049	19,591	0.40%

Source: International Cocoa Organization (ICCO) 2008.

[i] *Three-year average, 2005/06 – 2007/08 of net imports of cocoa beans plus gross imports of cocoa products converted to beans equivalent using the following conversion factors: cocoa butter 1.33; cocoa powder and cake 1.18; cocoa paste/liquor 1.25.

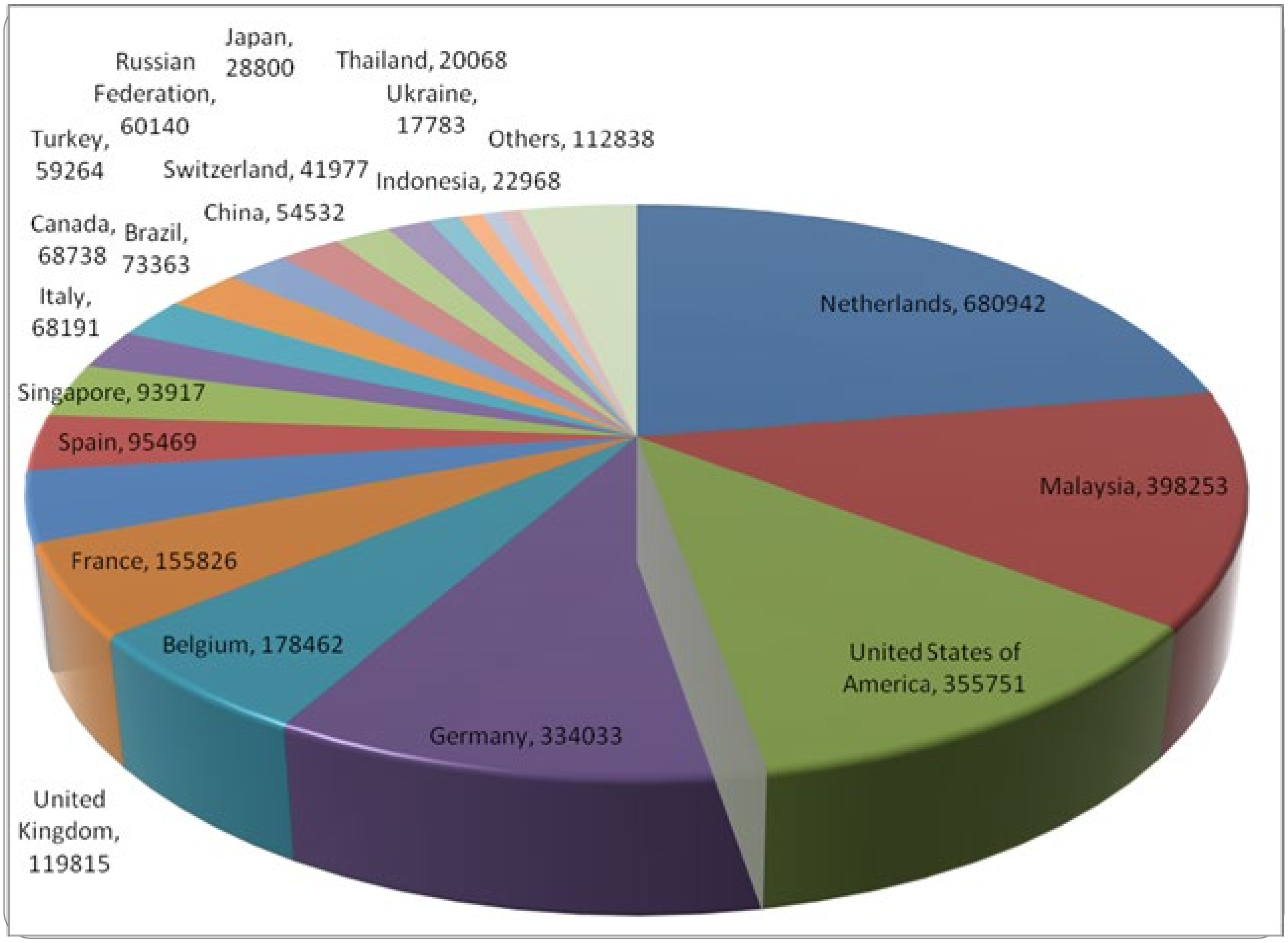


Figure 6: Share of main consuming countries in 2009 (Qty)

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

According to the ICCO's (2000) report, it was realized that during the second half of the 1980s, the divergence which existed between supply and demand was caused by excess production of cocoa. The cocoa price is very sensitive to changes in supply since supply cannot quickly adjust to changes in demand, due to slow maturity of cocoa trees and inability of farmers to switch to other crops in times of supply surplus (Lundstedt et al, 2009). Four West African countries (Côte D'Ivoire, Ghana, Nigeria and Togo) rank among the first nine top exporters to the World Market of Cocoa beans (See Figure 7 below). Cocoa production from the West African region is very vital to the World as a whole. Therefore, factors that hinder its production are usually worth studying.

Several structural reforms are also on-going in the cocoa industry, changing inventory practices, and the progress of privatization in key SSA producing countries have compounded traditional uncertainties associated with cocoa pricing. The production uniqueness of cocoa contributes to a long-term price cycle. In other words, it is difficult to quickly adjust supply to demand conditions.

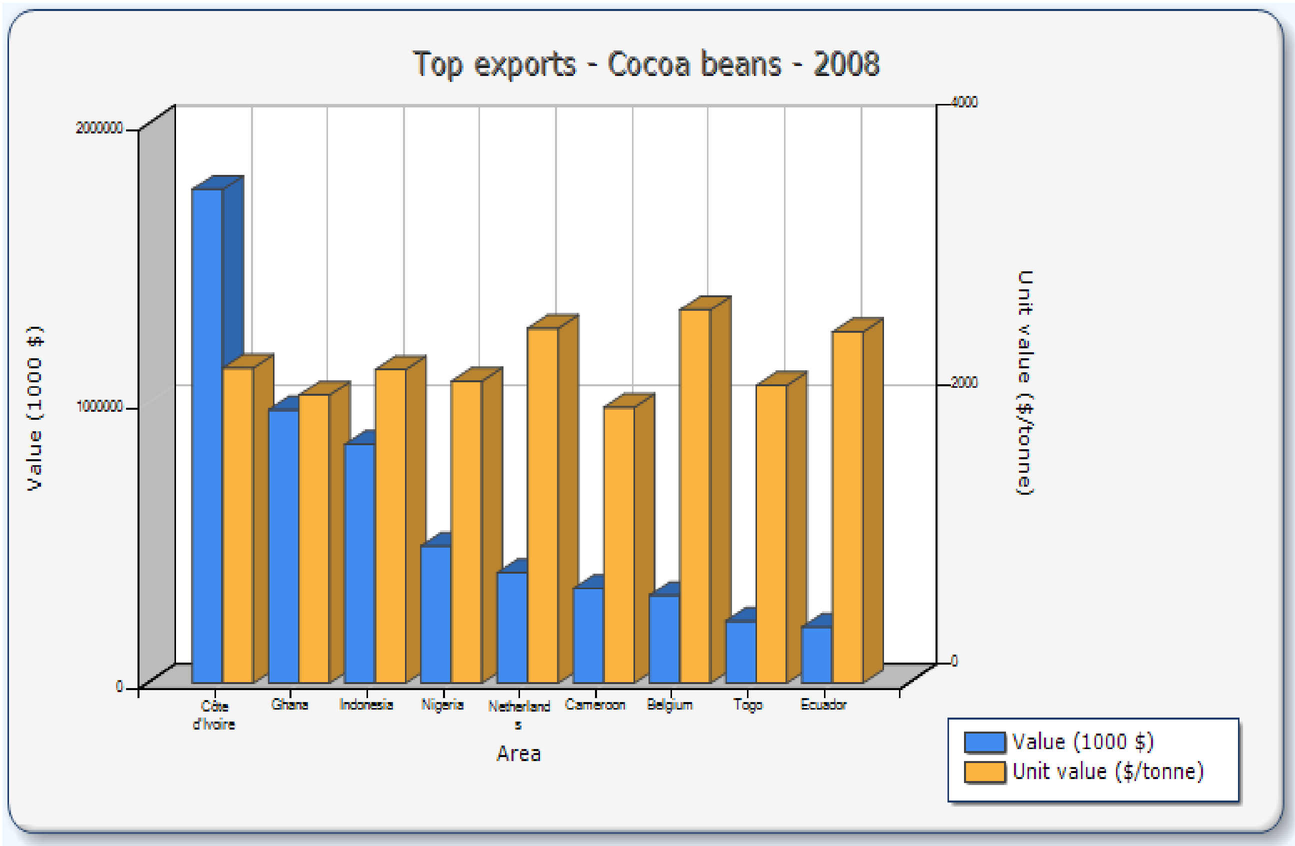


Figure 7: Top export of cocoa beans to the World Market

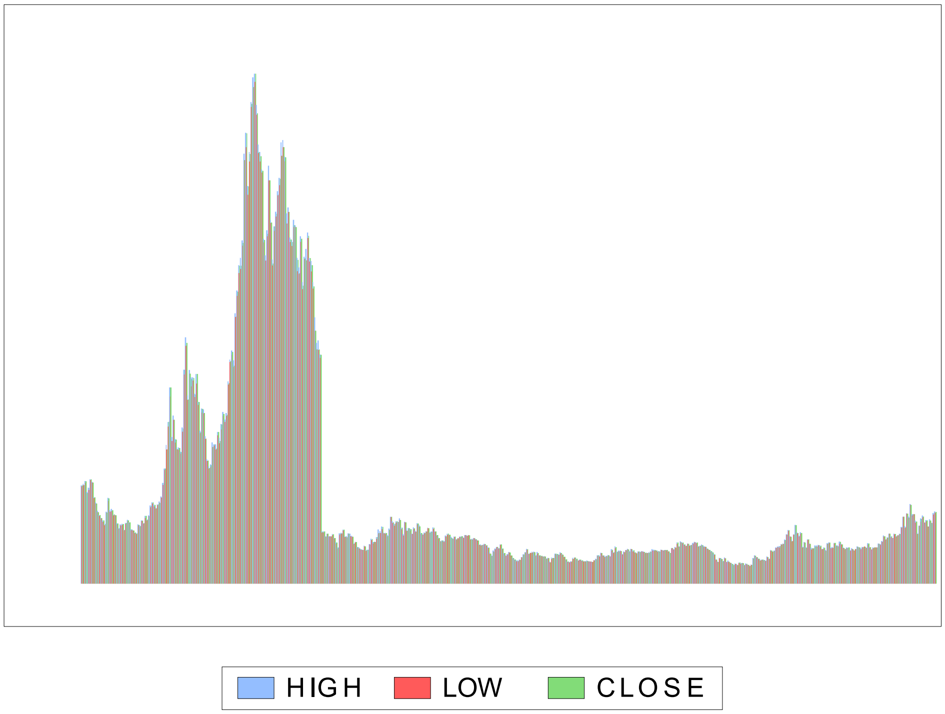
Source: FAO Agrostat, 2009.

A surplus or shortage can lead to erratic prices long before the cash market can adjust to the supply of cocoa. Figure 8 below illustrates the historical trend of cocoa cash price during the period 1966-2009. It is evident from the graph that cocoa spot prices at expiration[4] exhibit unpredictable pattern.

World cocoa bean prices have tended to exhibit an inverse relationship with changes in world stocks of cocoa beans. A sharp reduction in stocks in 2000/01 led to an increase of 13 percent in world cocoa prices. On the other hand, the average international cocoa prices increased in 2006/07 from the previous cocoa year by 19 percent per ton. The large production deficit in the 2006/07 cocoa season had been the main factor leading to this development in the market (ICCO Annual Report, 2006/07). The magnitude of cocoa price changes is often greater than the size of average profit margins along the marketing chain. For instance, from December 2001 to April 2002, the price of the nearby cocoa futures contract jumped more than 50 percent.

[4] Expiration is a marketing term used in the cocoa industry to reflect a period block or season.

Figure 8: CSCE Monthly Average Cocoa Cash Price at Expiration for Jan.1966 - Aug.2009



Source: ICCO Report, 2009.

Note: CSCE means Coffee, Sugar and Cocoa Exchange[5]

Figure 8: CSCE Monthly Average Cocoa Cash Price at Expiration for Jan. 1966-Aug. 2009

[5] This is a criteria used in measuring volatility in prices of these products. The essence for its use here is to show how erratic cocoa prices have been over the years.

Another factor that impacts on demand is elasticities facing the major consuming countries. A detailed examination of the price and income elasticities of demand for major selected cocoa consuming countries in the recent time produced interesting national elasticities as indicated in Table 3. Higher incomes as well as lower cocoa prices tend to increase the level of consumption. Changes in real income have a larger effect on consumption than changes in price of cocoa. For instance, according to the data in Table 3, a 10 percent decrease in the price of cocoa in the United States in the short-term could result in a 2 percent rise in consumption. However, a 10 percent increase of income could double the effect with 4.4 percents increase in consumption if the estimated elasticities were appropriate. Furthermore, cocoa represent small portion of the price composition of chocolate. Consequently, a reduction in the price of cocoa had a relatively smaller effect on the price of chocolate and its consumption than that of income.

In terms of annual decisions relating to the use of inputs and harvesting, the impact of prices is clear and strong. Short-term supply elasticities are positive, but do not exceed 0.25 in the major cocoa producing countries, for reasons of generally limited use of inputs. Although cocoa bean prices are only a small portion of the final consumer price of many products, demand for cocoa is still sensitive to prices, due to the considerable substitution possibilities of ingredients and products. Final consumer demand for cocoa displays a price elasticity of around –0.2 at world aggregate level; the income elasticity is substantial 0.85. There is a stable relationship between prices of cocoa beans on the world markets and the stocks-to-grindings ratio at a global level. Although some years have shown divergences from this pattern, including recent years, the relationship re-emerges time and again after such events, ICCO Annual Report, (2006).

Table 3: Price and Income Elasticities of Demand for Selected Major Cocoa Importing Countries.

Country	Elasticities	
	Price (Short Run)	**Income (Short Run)**
United States	-0.20	0.44
Germany	-0.15	0.50
United Kingdom	-0.24	1.00
France	-0.10	0.71
Japan	-0.28	0.54
Russian Federation	-0.18	0.42
Brazil	-0.23	0.40
Spain	-0.27	0.32
Belgium/Luxembourg	-0.23	0.80
Canada	-0.18	0.26
Switzerland	-0.09	0.44
World	-0.2	0.85

Source: ICCO and UNCTAD, 2009.

2.3 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 declined 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 recently 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.

In terms of country specifics, Nigeria was one of the leading producers of cocoa in the world in the 1970's where the Marketing Board, Nigerian Cocoa Board (NCB) was the sole buyer and exporter of cocoa and controlled the internal market chain. The NCB was abolished in 1986, as part of more general economic reforms, and prices were, thus, set by market forces, leading to higher, but more volatile prices and an abandoned quality control. As an effect of internal market liberalization, private players have started to provide additional services to farmers, leading to higher quality control and credit possibilities (Lundstedt et al, 2009).

In Côte D'Ivoire, prior to liberalization, private exporters were allowed to operate on the market even if both internal and external markets were controlled by a state-owned company. In the middle of the 1990s, state control was diminished, in order to reduce marketing costs, raise producer prices and encourage the creation of producers' organizations (Lundstedt et al, 2009). The reforms increased production, but did not lead to sufficient changes for farmers, which brought about further liberalization reforms in 1999. This led to a reconstruction of the state owned company, which only got a limited monitoring role, and a full liberalization of the producer price (Lundstedt et al, 2009).

Prior to liberalization in Togo, cocoa prices as well as external and internal market were controlled by a Marketing Board. The country undertook a profound liberalization of its cocoa sector in 1996, in order to increase producer incomes and develop private export participation, and maintain a high quality of produced cocoa (Gockowski, Weise, Sonwa, Tchtat, and Ngobo, 2004). This was achieved through an inclusion of the private sector in the design stage of the reform process, a clear dialogue with all participants in order to coordinate all interests and a detailed information system on international market prices to enable producers to more easily choose between buyers and receive proper prices. The reforms increased the producers' share of the world market price from under 60 percent before the reform to around 80 percent in 1997, resulting in increased production (Lundstedt et al, 2009). Due to the cooperation between the government and private actors concerning quality control, a high quality level was maintained and Togo still receives a higher cocoa price than average world market price.

In 1947, the Cocoa Marketing Board (CMB) in Ghana was established and given sole responsibility of exporting cocoa through its wholly-owned subsidiary, the Cocoa Marketing Company (CMC). The main beneficiary of export earnings was the government. Several licensed buying companies (LBCs) operated on the internal market as buying and transporting companies for the CMB. The producer price was determined by the world market price and a tax, but the system was eventually abandoned in favour of a marketing board system with fixed nominal producer prices that granted the CMB high shares of the world market price (Kishore, 2010). After independence in 1957, the responsibilities of the CMB and the structure of the cocoa sector remained unchanged until 1961 when the multiple buying systems were replaced by a monopsony system. This system was abandoned as early as 1966 and the system with licensed buying companies was re-introduced. At the same time, a state-owned buying company was established, the Produce Buying Company (PBC), to operate alongside the private-owned buying companies. The monopsony system was introduced again in 1977 with the PBC as the sole buying company operating on the internal market chain. After series of military takeovers, a market-oriented reform program was launched in 1983 and the late 1990s, supported by the Washington institutions, aimed at increasing GDP, reduced poverty and eliminated rent seeking behavior by government officials. The reforms of the cocoa sector were important elements of the overall reform process (Gockowski *et al,* 2004).

As a way to reduce the negative impact of price fluctuations on farmers, a fixed producer price is set every year by the Producer Price Review Committee (PPRC), comprising representatives from the government, COCOBOD, farmers, the LBCs, University of Ghana and different business groups. The producer price is a price floor. That is, the LBCs are not allowed to purchase cocoa for less than the producer price (Gockowski *et al,* 2004). Even though there are no formal restrictions against raising the price above the price floor, it is not raised above the minimum level. The producer price, which is based on the predicted average world market price of cocoa, is set in the beginning of each cropping year and is constant throughout the season. When the world market price of cocoa fluctuates, there is a discrepancy between the actual and the predicted price. This implies that there will be surpluses or deficits in relation to the targeted level depending on how the world market price fluctuates. The surplus is divided between the government and the farmers, while the deficit is covered by the government alone. Farmers receive the surplus in form of yearly bonuses after payment.

2.4 Trends of cocoa production in West Africa

Figure 9 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.

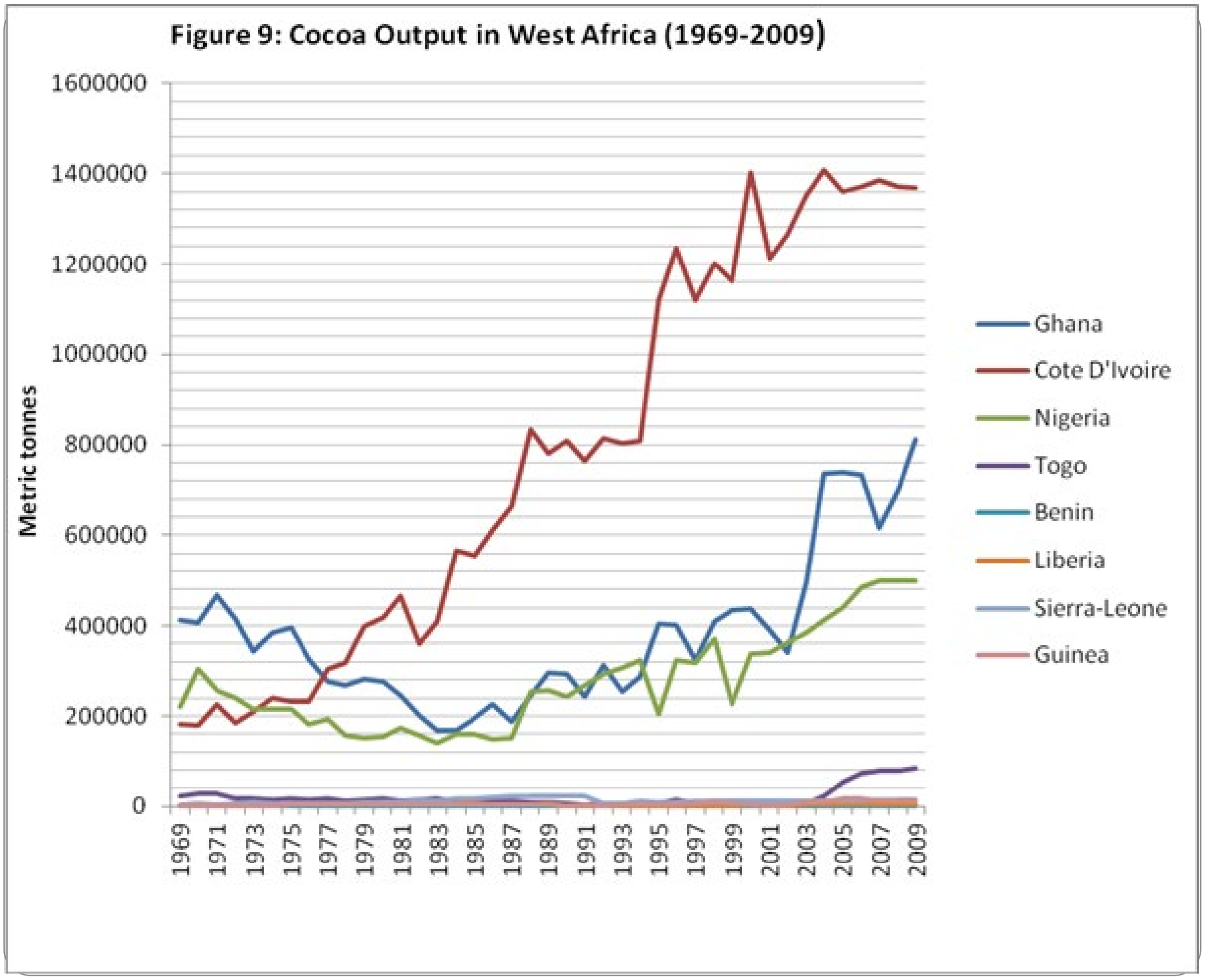


Figure 9: Cocoa Output in West Africa (1969-2009)

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

2.5 Trends of cocoa output, temperature and precipitation in West Africa

West Africa accounts for more than 70% of world cocoa production (Côte d'Ivoire 38%, Ghana 21%, Cameroon 5%[6] and Nigeria 5%). Côte d'Ivoire and Ghana are the world's two largest producers, representing 80% of total West African production. Cocoa is also produced in Togo, Sierra Leone and Liberia, Guinea, Benin albeit in much smaller quantities.

The temperature and precipitation data used here are those of the cocoa producing areas instead of the country meteorological data. The cocoa producing areas considered for the study in the respective countries are as follows: Ghana: Sefwei Yiawso, Togo: Sotoubouo, Benin: Djougou, Sierra Leone: Ngiehum, Nigeria: Ekiti state, Cote D'Ivoire: Yawusukrom (Bouake), Guinea: Macenta, Liberia: Grand Bassa County. The map below (figure 10) constitutes the cocoa producing areas in West Africa.

Figures 11, 12 and 13 report trends in output of cocoa and the two main climatic variables capable of influencing cocoa production in West Africa. These variables are temperature and precipitation. The countries under consideration are grouped into two with one representing the leading cocoa producing countries from West Africa to the World Market and the other as small cocoa producing countries from West Africa to the World Market.

[6] Cameroon not considered under this study because it is politically demarcated under Central Africa.

Figure 10: Main Cocoa Production Zones in West Africa.

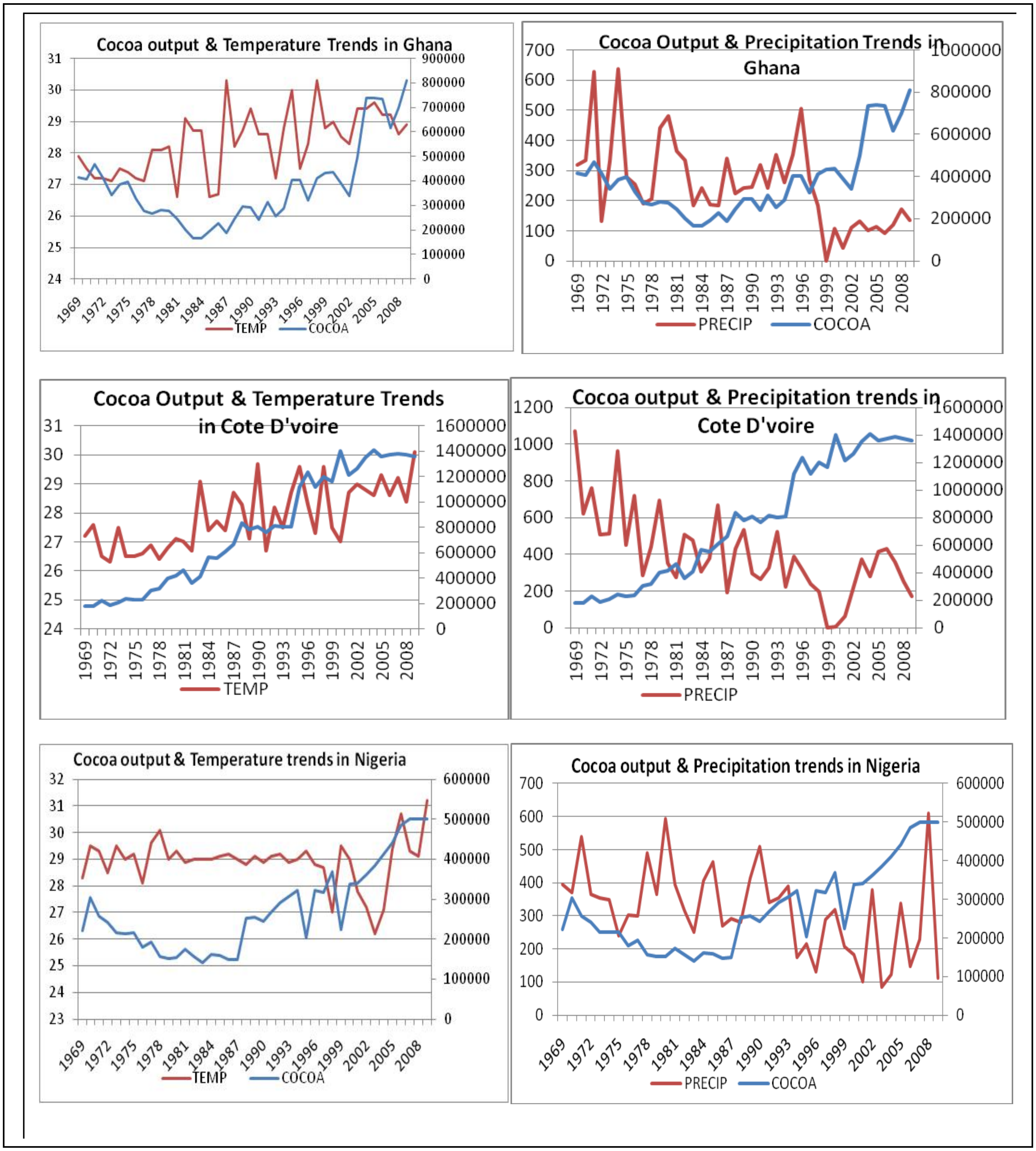


Figure 11: Trends of major contributors of cocoa beans from West Africa to the World

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

Figure 11 reports trend analysis of Ghana, Cote D'lvoire and Nigeria. The graphs on all the three countries indicate that temperature generally have shown increasing trend in Cote D'Ivoire and Ghana overtime but that of Nigeria has been rather stable except for the last decade where temperature has been observed as increasing. In Ghana, temperature widely fluctuated in the 80's and throughout the 90's. Cote D'lvoire has witnessed wide temperature fluctuations throughout the study period (1969-2009). Among the three countries Nigeria has had a fair distribution of temperature except for early part of the 1970's and the 2000's. Cocoa output has also been rising among all the three countries, except for Cote D'lvoire which has experienced sharp decline from 2005 to date. Therefore, cocoa production and temperature can be described as having approximately a increasing trend across the study period.

In terms of precipitation, there has been declining trend throughout the study period for all the three countries represented in figure 10. Ghana, however, experienced a increasing precipitation at the end of 2008 and 2009. Generally, except for fluctuations in precipitation, there has been a declining trend among these countries. Whereas cocoa production is increasing, precipitation is declining across the three countries over the study period.

Figures 12 and 13 reports the analysis of small cocoa contributors from West Africa to the World Market. These countries include Togo, Benin, Liberia, Sierra Leone and Guinea. In general terms, there has been a rising trend in temperature and cocoa production over the study period and across all these countries. Togo has experienced fluctuations in temperature and precipitation throughout the study period with shaper variations occurring in the late 1990's and early 2000. Cocoa production in Togo has dwindled since the late 70's till 2005 where it started rising to date.

Benin observed high temperature surges in 1969 and 1999 with heavy fluctuations across the study period. Precipitation has also been unevenly distributed over the study period with large fluctuations occurring from 2005 to date. Production of cocoa in Benin has generally been very low except for 1997, and started declining again till 2005 where there was marginal rise. Since then cocoa production has been declining to date

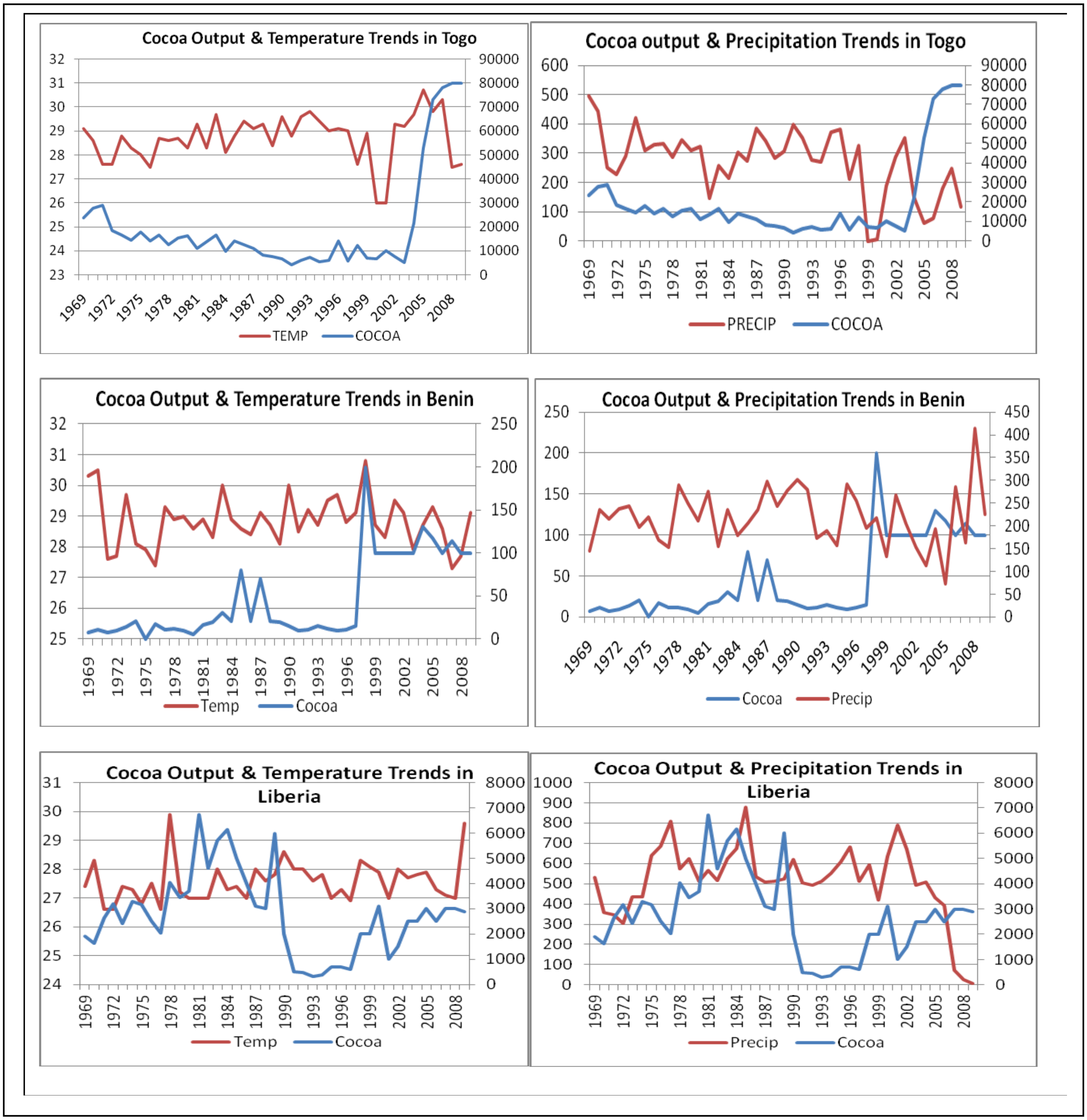


Figure 12: Trends of small contributors of Cocoa beans from West Africa to the World Market

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

Liberia has also witnessed increasing temperature trends over the study period with the peak recorded in 1978 and 2008. Precipitation has generally been falling with the lowest precipitation occurring in the 2000's. Cocoa production in Liberia hit the highest point in the late 1970's and has since been falling up to date with the lowest fall recorded in 1990-1996.

Figure 13 shows that Sierra Leone records higher precipitation than all the countries under study and within the study period. However, precipitation in Sierra Leone like all the other countries under study have shown declining trends over the study period. Temperature has also been rising over the years with the highest records found in 2007. Temperature and precipitation fluctuations have also been prevalent in Sierra Leone throughout the study period like all other countries under study. Cocoa production in Sierra-Leone has generally followed an increasing path with the climax recorded in 1989. After this period cocoa production fell precipitously till 1993 and have since risen marginally to date.

Guinea is the only country among the countries under study that has envisaged high level of temperature trends across the period of study. However, temperature in this country is fairly distributed throughout the period under study. In terms of precipitation, Guinea has witnessed a declining and undulating trend over the years. Like all the other countries covered, cocoa production has been increasing in Guinea over the years except for declining trend in the late 2008 to date.

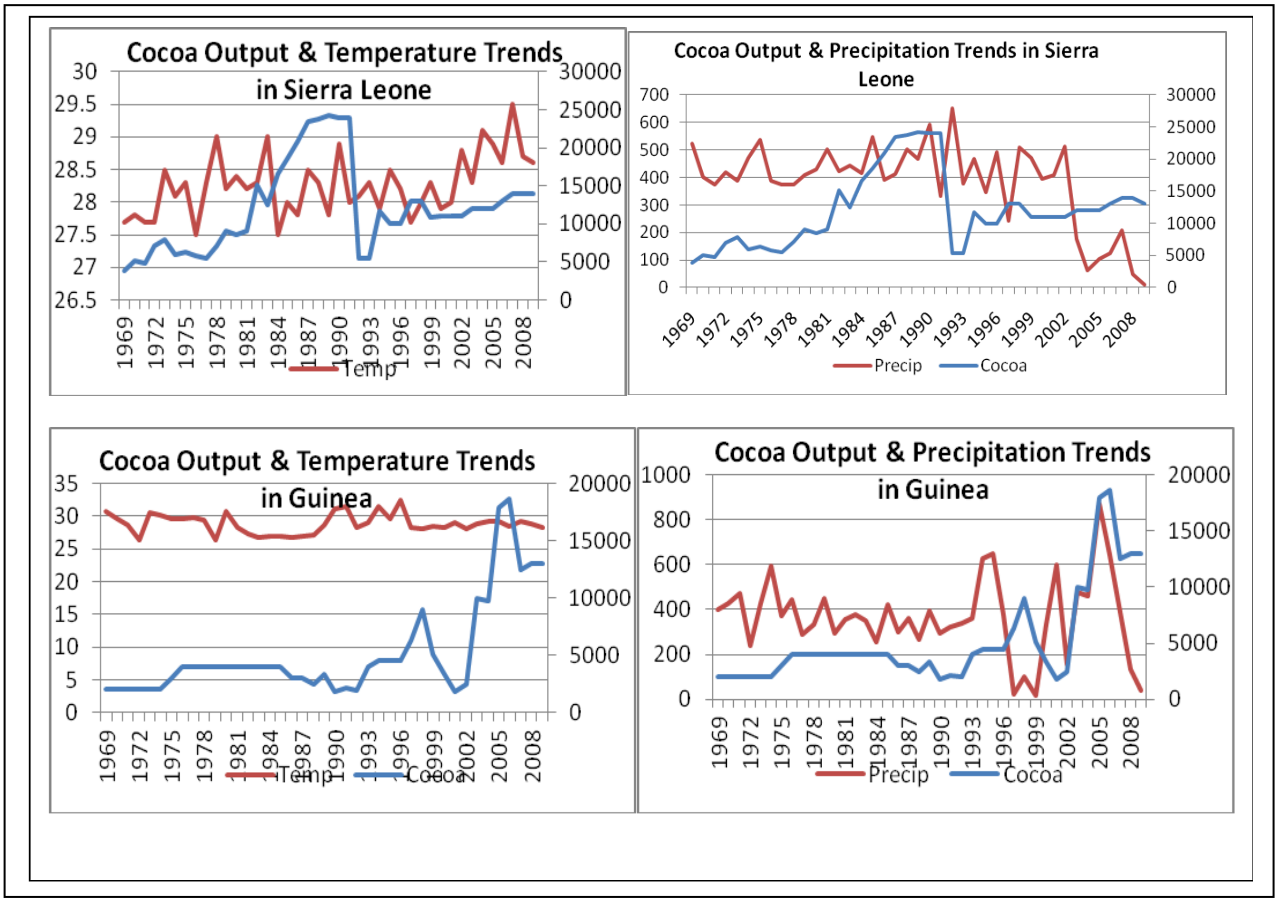


Figure 13: Trends of Cocoa beans from Sierra Leone and Guinea to the World Market

Source: FAO Climpag data plotted by the Author 2011.

CHAPTER THREE

LITERATURE REVIEW

This section presents a review of relevant theoretical, methodological and empirical literature relating to the impact of climate change on cocoa production in West Africa. Four major theories underpin cocoa production and climate change. Various methodological approaches have also been extensively reviewed in this study. The methodologies designed by the authors were carefully considered in grouping the reviewed studies. Also, this section examines the empirical review of literature which has been grouped according to the findings that emanated from the studies.

3.1. Theoretical review

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).

3.1.1. Ricardian theory

This theory[7] 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[8]. The general model is specified as:

$$z = \sum_i \left[\alpha_i T_i + \beta T_i^2 + \gamma_i + \delta_i P_i^2 \right] + K \qquad (1)$$

Where z is the measure of agricultural productivity (net revenue per hectare), T is the average temperature, P is average monthly rainfall, i refers to the season, and K is a composite variable that reflects the regression constant as well as the influence of other control variables in the particular model estimated.

[7] The theory was popularized by Mendelsohn and Neumann (1999) and has been used extensively by the World Bank for assessing the impact of climate change on farm yields.
[8] See for example (Mendelsohn and Nordhaus, 1999b; Mendelsohn and Dinar, 2003).

The theory proceeds on the assumption that farmers maximize net revenues per hectare (NR). Thus, $MaxNR = P_i * Q_i(R,E) - C_i(Q_i, R, E)$ (2)

Here P_i and Q_i are respectively the price and quantity of good i; C_i(.) is the relevant cost function; R is a vector of inputs, and E reflects a vector of environmental characteristics of the farmer's land including climate. Given that the farmer chooses inputs, R, to maximize NR, the net revenue function NR can be expressed in terms of E alone as:

$$NR = f(E) \qquad (3)$$

To cater for the welfare value of a change in the environment from state *A* to *B* the model becomes:

$$W = \sum f(E_{iB}) * L_i - \sum f(E_{iA}) * L_i \qquad (4)$$

Where L_i is the amount of land of type i. Equation (4) enables Cross-sectional observations across different climates to reveal the climate sensitivity of farms. The merits of this model are that it does not only allow for the direct effect of climate on productivity, but also the adaptation response by farmers to local climate.

Agronomic literature and casual observation over the years reveals that many crops have preferred temperature and precipitation zones[9]. Temperatures and precipitation levels either below or above such optimal ranges reduce productivity. The evidence suggests that the relationship between net revenue and these climate variables should be hill-shaped. Consequently Dinar *et al.*(1998) suggest the quadratic functional form of the Ricardian model as:

$$NR_i = \alpha_0 + \sum(a_s T_s + b_s T_s^2 + c_s P_s + d_s P_s) + \sum f_c + Z_c + \varepsilon \qquad (5)$$

Where T_s and P_s represent normal temperature and precipitation variables in each season; and Z_c represent relevant socio-economic variables.

The original Ricardian studies used land value for the dependent variable but many developing countries lack land value information and therefore resort to annual net revenue

[9] Darwin, R. (1999), 'The impact of global warming on agriculture, a Ricardian analysis: Comment', The American Economic Review **89**: 1049–1052.

per hectare instead[10]. The use of annual net revenues, however, introduces some potential problem since the net revenue in any one-year is influenced by the weather in that year. Arising from this, the Ricardian model has been carped of on several counts. One stance in the literature is that the original estimates did not include surface water or irrigation (Cline, 1996 and Schlenker *et al.*, 2003) and that the method cannot measure the effect of variables that do not vary across space such as CO_2. It is also criticized on grounds that the method measures long-run adaptation, but not the speed of adaptation and that the model assumes current technology, implying that it does not take into account technology that may be available in the future. Again, the model assumes no price effects (Darwin, 1999) so that if climate change alters supplies of individual crops, prices are likely to change[11].

3.1.2. The Agricultural Investment Portfolio Model (AIPM)

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 setup considers a farmer with total asset holdings (wealth) W and allocates his n production assets prior to the realization of a random weather outcome w in order to maximize his expected utility of consumption. Due to the direct estimates of the effects on the investment portfolio of measured characteristics of the distribution of the stochastic weather variable, the model particularly makes it convenient to represent the farmer's expected utility

[10] Since land value is the present value of a future stream of net revenue (Dinar et al., 1998).

[11] In spite of all the criticism leveled against the Ricardian model, others believe that these problems are significant but not fatal (Mendelsohn, 2001). CO_2 effects could be included exogenously as new technology. Global prices are not expected to change dramatically as a result of climate change (Reilly et al., 1996). More recent studies have found that irrigation and surface water do not influence climate sensitivity (Mendelsohn and Nordhaus, 1999b; Mendelsohn and Dinar, 2003).

rankings for consumption in terms of his preference ordering over moments of the distribution of consumption.

Thus, it becomes straightforward to map changes in the moments of the observed stochastic variable (weather) into changes in the moments of the consumption distribution. Moreover, Meyer (1987) has demonstrated that the consistency of the two sets of rankings for the first two moments of the distribution of payoffs is when the stochastic payoff variables differ from each other only by location and scale parameters. Under this condition a wide variety of functional forms for expected utility models are consistent with models incorporating mean-standard deviation rankings. Consequently the farmer maximizes:

$$U = V(\mu_c, \sigma_c) \qquad (6)$$

$$V_\mu > 0, V_\sigma > 0.$$

Where μ_c and σ_c are the mean and standard deviation of consumption respectively[12]. The farmer is able to influence the arguments in (6) by choosing an appropriate mix of production investments. Normalizing arbitrarily by the n^{th} production asset and assuming a profit function to be linearly homogenous in the investment inputs, which leads to expression of a relationship between the mean and standard deviation of farmer profits μ_Π and σ_Π , the productive investment portfolio vector α_i (where the element α_i = the share of the i^{th} investment input in total wealth), and the mean and standard deviation of the stochastic weather distribution μ_ϖ and σ_ϖ are respectively as:

$$\mu_\Pi = Wf(\overline{\alpha}_i)\mu_\Pi \qquad (7)$$

and

$$\sigma_\Pi = W\Gamma(\overline{\alpha}_i)\sigma_\varpi \qquad (8)$$

[12] Meyer has also demonstrated that the quasi-concavity of (6) is sufficient to guarantee convexity of preferences, so that $V_{\mu\mu}, V_{\sigma\sigma} < 0$ and $V_{\mu\mu}, V_{\sigma\sigma} - V_{\sigma\mu}^2 \geq 0.$

$f\alpha\alpha, \Gamma\alpha\alpha < 0.$[13]

The two equations above assume that the mean and standard deviation of profits per unit of wealth are homogenous of degree 0 in total wealth W. They are homogeneous of degree one in the first two moments, respectively of the weather distribution[14]. Also, the model assumes there is only one source of stochastic variability in profits. This makes it straightforward to consider multiple weather shocks, in any functional form that is used. With one source of profit variability, Γ measures the riskiness of the asset portfolio. The mean of consumption is therefore represented as:

$$\mu_c = \mu_\Pi \qquad (9)$$

Just and Pope (1978) opined that the mapping of the standard deviation in profits to that of consumption depends on what is assumed about capital market constraints. If assets cannot be sold and borrowing is not possible then $\sigma_c = \sigma_\Pi$, as is assumed in farm risk studies, on the other hand, if farmers are fully insured against income fluctuations $\sigma = 0$, as assumed in most theoretical studies of savings based on the permanent income hypothesis (see for example, Wolpin, 1980; Paxson, 1992). Moreover, the sensitivity of consumption variability to ex post profit variability may depend on the total level of asset holdings, for which there may be a limited market and which may serve as collateral for loans. Rosenzweig and Stark (1989), for example, noted that the association between the variances of intertemporal profits and consumption was significantly lower for some countries where farmers had greater inherited wealth.

Recent evidence in the literature (Rosenzweig, 1988; Rosenzweig and Stark, 1989; Walker and Jodha, 1986), suggests, however, that rural agents employ a variety of formal and informal mechanisms that contribute to ex post consumption-smoothing and identifies agents as successful in insuring against all non-covariant risk, in particular all risk that is not common to agents residing in a given village (Townsend, 1990). This evidence suggests that measuring

[13] Homogeneity for the weather variable is similar to most specifications of stochastic output in the theoretical literature on agricultural risk utilizing the expected utility framework (see Feder 1977).

[14] The homogeneity assumption for the weather variable is similar to most specifications of stochastic output in the theoretical literature on agricultural risk utilizing the expected utility framework (see Feder 1977)

risk preferences based on the relationship between moments of the distribution function of total farmer profits may not be appropriate because not all of profit riskiness affects utility, as is assumed in the farm-based studies. Estimates of consumption preferences cannot be obtained without specifying the constraints facing agents, in particular, the mechanisms they have established for ex post consumption-smoothing inclusive of stock accumulation.

3.1.3. Crop Yield Response Theory (CYRT)

This 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[15]. The setup assumes a log-normal distribution of W such that in Cobb-Douglas specification the equation is written as:

$$P = aL^{1}N^{n}K^{k}W^{w} \qquad (10)$$

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[16]:

$$InP = \alpha + \sum \beta_i Inx_i + \sum_i \sum_j \delta_{ij}(Inx_i)(Inx_j) \qquad (11)$$

[15] Oury in 1965 revisited the ideas of all the earlier studies on this topic “Allowing for Weather in Crop Production Model Building” and his work has since become the basis for most crop insurance studies in the advanced countries.
[16] See for example (Lau, 1986; Sauer et al., 2004).

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). Furthermore, the choice of a functional form is usually based on the need to ensure rigorous theoretical consistency and factual conformity within a given domain of application as well as flexibility and computational ease (Lau, 1986; Sauer et al., 2004). Whatever functional form that is used, the basis of the theory in the literature is that the arguments incorporate both cost and noncost inputs in the production analysis.

Stallings (1959) hypothesized that if time series of yields can be obtained from experimental plots in the areas where the particular crops are grown (where all practices were held constant), the remaining variation in yield from year to year should give an indication of the influence of weather after trend has been removed to account for changes in soil fertility. He assumes that all variations in plot yields due to non-weather factors not correlated with weather are randomly and normally distributed with an expected value of zero, and that by removing the time trend it is possible to measure for each year the deviations of actual yield from computed yield.

Recent literature, see for example, Shaw (1964) and Thompson (1963) have attempted different approaches to investigate how much of the increase in crop output can be attributed to weather and how much to technological advance allowed for by a time trend. Shaw (1964) hypothesized that a weather measure must take into account the level of technology that exists at each point in time and used experimental plot data that allowed for changes in technology. Thompson (1963) rather applies ultimately historical parabolic pattern of crop yields over time, which is highly arguable and perhaps inconsistent to most literature. It refers to the right part of a downward convex parabolic curve in a situation of growing rate of increase toward an unlimited value.

Issues with this theory however are that deriving the yield distribution from those of weather variables during all stages of the growth period of a crop, or merely during the critical stages, raises the question of how to delineate those stages: example, months, weeks or days. If the weather variance may be used as an indicator of weather risk, presumably the most critical stage of a plant's growth is likely to be the one where the historical variance of weather is the greatest (Oury, 1965). As noted by fisher (1920), was it is possible to ignore the influence of weather during those stages of lesser weather variance without weakening the explanation. Some studies visualizes such inherent problem and suggests that weighting the weather data for each stage of growth (month, week, day) via historical variance and collapsing the several weather variables into a single one covering the entire growth period serves a better purpose (Oury, 1965). Also, the determinants of weather are numerous and their interrelationships very complicated. They interact with non-weather factors as well. Furthermore, the problem of weather influence upon agricultural output raises a much broader question. How much of the changes in yield, acreage, and consequently output are attributable to weather, how much to economic factors, how much to technology, how much to institutional factors (That is, government policy), as all these factors interact in numerous ways (Oury, 1965).

3.1.4. Metaeconomics Theoretical Model (MTM)[17]

The underlying precept of this model[18] is on how much influence weather information forecasts have on decisions of farmers[19]. In particular, it is a test on the hypothesis of joint pursuit of both the egocentric self-interest Q_G and the empathetic other-interest Q_M, both internal to the self of an individual[20]. It posits that farmers pursue other interests besides self-interest[21]. Willock et al (1999) discovered that farmers ranked their job satisfaction over profit

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[17] The MTM is a new theory which originated in the 1990's arising from the continual threatening nature of weather on crop production in many parts of the world.

[18] Metaeconomics proposes that (after Lynne, 1999; 2002) farmers are not only rational producers, but also at base are far more emotional than usually considered. It is a real possibility that farmers not only seek profits (driven by an underlying feeling about the need for material goods, wealth) but also want to feel they are in unity with the community (and perhaps with nature, the place in which they farm, itself) with its values and norms.

[19] Cognitively conscious and rational choice involves finding the best integration and orientation in pursuit of both individual profit and unity with community, seeing farmers as seeking a kind of peace of mind in the pursuit of these oft times conflicting interests.

[20] Lynne et al. (1995) concluded that farmers displayed characteristics of both, as he calls, homo economicus and homo sociologicus.

[21] Artikov I, and G.D Lynne, 2005. Climate and Farm Use of Weather Information, American Agricultural Economics Association Meeting, Providence, Rhode Island, pp. 24-27.

maximizing incentives in production behavior and tended to perceive themselves in unity with the environment and community that they resided by complying with the rules or norms[22].The theory assumes that since an idea of sub-selves is valid, then the symbolic Q_M as the other (empathetic)-interest along with an established self-interest Q_G emerge as substantial factors in producer decisions.

The choice and mix of inputs are therefore described by the attributes of inputs X_j . X_f and is presumably an individualistic technology which is oriented to the more self-directed farmers that mainly pursue profit maximizing goals. X_0 is a community-related technology that is oriented to a more other-directed farmer who is more oriented to being in unity with environment and community, and being concerned for the sustainability of the larger community. The latter might be manifested in ensuring fertilizer does not enter an adjacent waterway or in sharing water with neighbors during a drought, both perhaps better ensured by closely following weather and climate forecast and information. The choice and mix of these inputs is represented in two jointly occurring interest or production functions below:

$$Q_G = Q_G(X_f, X_0) \qquad (12)$$

$$Q_M = Q_M(X_f, X_0) \qquad (13)$$

Equations (12) and (13) are described as nonseparable outputs in a multi-ware production process when Frisch (1965) used wool and mutton production as experiment. The major feature of multi-ware, multi-output joint and nonseparable production processes is the little to no possibility to affect the balance of these outputs. In other words, the inputs are non-allocable in contrast to being allocable, the latter generally assumed in multiple output production in standard microeconomics (Lynne 1988).

Hayes and Lynne (1965) opined that there is the possibility of fitting the idea to many functional forms. Consequently, the metaeconomics model was derived with the objective function as:

$$\Phi = \iota p Q_G(X_f, X_0) + \tau Q_M(X_f, X_o) + \gamma(Q_G)(Q_M) + \lambda(R - k_f r_f X_f - k_o r_o X_o) \qquad (14)$$

[22] Sober and Wilson (2002) argued that people have both egoistic-hedonistic and empathetic altruistic tendencies. Etzioni (1988) proposed the idea of people pursuing at least two irreducible utilities (cited in Kruse, 2003).

Where r_f refers to the input prices paid for the attributes X_f by this firm, (P) is the market generated price for the egoistic interest in providing this product, k_f, k_0 are subjective elements added to cost and input prices because farmers see costs in more complex ways than the monetary value of the item alone (Hayes and Lynne, 2004).

As the value of ι increases, the farmer is orienting the internal self toward the egocentric self-interest. Unlike the objective price, Q_M function carries a subjective element τ which reflects the degree of the farmer's orientation toward the empathetic other-interest, such as having strong tendencies toward building social capital in the community. Jointness between the interests, synergy and interdependence is illustrated in the term $\gamma(Q_G Q_M)$. After taking partial derivatives with respect to the perceived attributes of the inputs, the least-cost expansion path that satisfies and suggests the orientation in the interests is determined as[23]:

$$\frac{(\iota p+\gamma Q_M)\frac{dQ_G}{dX_f}+(\tau+\gamma Q_G)\frac{dQ_M}{dX_f}}{(\iota p+\gamma Q_M)\frac{dQ_G}{dX_0}+(\tau+\gamma Q_G)\frac{dQ_M}{dX_0}}=\frac{k_f r_f}{k_0 r_0} \tag{15}$$

When $\iota = k = 1; \tau = 0; \gamma = 0,$ then equation (15) is described as the standard microeconomics expansion path. The model hypothesize that the egocentric path ignores the orientation and interdependence in the interests and empathy is ignored as an underlying factor in driving interests. As such the expansion path from equation (15) becomes:

$$X_0 = X_0(Q_G, Q_M, k_0 r_0 k_f r_f, p, X_f) \tag{16}$$

Equation (16) indicates that product and input prices as well as the values of (Q_G) and (Q_M) variables affect the expansion path. Under the assumptions of two symbiotically oriented interests, the derived demand function for weather information and forecasts becomes:

$$X_f^D = X_f^D(k_f r_f, k_0 r_0, p, Q_G, Q_M, R) \tag{17}$$

The superscript D refers to discipline in the context of integrating the two interest along the path OZ. R is a constraint represented in natural capital including climate zone; social capital

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[23] Lynne, G.D., Cutforth, L., and K. Eskridge, Balancing the Egoistic and Empathetic Tendencies While Seeking Agrobiodiversity: Testing Metaeconomics Theory.

(such as constraints on volition; extent of control over the individual; perceived control, and preferences for control, by the individual as well as the traditional financial capital).

Another major focus of metaeconomics is on the derivative $d(Q_G) / d(Q_M)$ that reflects the trade-off or balance between self and the "other"-interest along the frontier for a particular R. The trade off equation then becomes[24]:

$$d(Q_M)/d(Q_G) = -\frac{d\Phi}{dQ_M} / \frac{d\Phi}{dQ_G} = -\frac{\tau + \gamma Q_G}{\iota p + \gamma Q_M} = T_{GM} \qquad (18)$$

When $\gamma = 0,\ T_{GM} = -(\tau / \iota p)$, which displays the ratio of subjective element of the empathetic attributes of the decision to the objective market based ones. Lynne et al. (1995) observes that microeconomic theory directly presumes $\iota = 1, \tau = 0,$ and $\gamma = 0.$ In this case, market prices of inputs become the only substantial attributes of the farm decisions[25]. If $T_{G/M} = 0$, it means there is only a self-interest driving the decision (the Q_G). This reflects the path of the egocentric, profit-maximizing individual who is not concerned with the community at all, at least not in any significant or substantive way. In contrast, if weather and climate forecast information is to be primarily used as a shared public good (example, shared "other"-interest),the theory perceives farm firm is to subdue the self-interest and use input combinations in the "other"-interest along some (maximizing) expansion path where $T_{GM} = -\infty,$ and, in the extreme event where $T_{GM} > 0$, the irrational zone[26]. As with the demand for inputs, the subjective element represented in Q_M, -the empathy, also now is a force in commodity supply. Overall, in metaeconomics, the reaction to price and price ratios is influenced by subjective measures of

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[24] The equation (17) and the objective function (18) are used to derive equation 18. Further reading can look at Ziervogel, G. "Targeting Seasonal Climate Forecasts for Integration into Household Level Decisions: the Case of Smallholder Farmers in Lesotho." The Geo. J. 170,1 (2004): 6–21.

[25] Cutforth, B. L., Francis, A.C., Lynne, G.D., Mortensen, D.A., and K.M. Eskeridge. "Factors Affecting Farmers' Crop Diversity Decisions: an Integrated Approach." Amer. J. Alt. Agr. 16 (2001):168-76. Also Kruse, C. "Carbon Sequestration and Social Sciences." Master's Thesis, University of Nebraska-Lincoln, 2003.

[26] The outcome in metaeconomics depends on the reasoned, synergetic and perhaps even symbiotic, sum greater than sum of parts and joint interest orientation at work, which is reflected in the ratio $-\infty < T_{GM} < 0$ .This Allows the determination of a joint and unique mix of the weather information using practices at some point on their production frontier where they do not maximize their well being as in $T = 0$. See for example Simon (1957).

value reflecting how the egoistic and empathetic forces are symbiotically integrated and oriented by the disciplined decision maker. In the absence of the discipline a farmer may act as an unbalanced, non-integrating maximizer oriented completely to only the selfish interest. The same is true about those who pursue solely their own internalized other-interest without much concern for profit.

The synthesis is that metaeconomics emerges as a promising theory and approach in adding further understanding of economic behavior. The metaeconomics model shows that farmers are dual and jointly-interested individuals who are influenced by the social context; also, it displays significance of internal decision elements by focusing on the interactive balancing and orientation in the nature of the interests and overall potential or capacity that drives behavior.

3.2. Methodological review

Diverse approaches have been observed in the methodological literature in assessing the impact of climate change on agricultural produce as a whole due to the several channels involved. Faced with these different channels, this section groups the various methods used in the literature and discuses their weaknesses as well as their strengths.

3.2.1. Integrated Assessment Models (IAM)/ General Equilibrium Models (GEM)

With regards to the methodological review, the traditional approach to estimating the overall economic impact of climate change has been the use of "Integrated Assessment Models" (IAM), which take some subset of mechanisms, specify their effects, and then add them up (see, Mendelsohn et al. 2000, Bamba 2000, Tol 2002). For example, Quiroga and Iglesias (2007) in providing monetary estimates of the impact of climate change in European agricultural sector for future scenarios, incorporated socio-economic projections and conducted the experiments using global climate models and regional climate models. To examine the impact of climate on agricultural trade flows, the quantitative results were based on simulations using the GTAP general equilibrium models system which usually includes all relevant economic activities. Zhai, Lin and Byambadorj (2009) in examining the possible long-term impact of global climate change on agricultural production and trade in the People's Republic of China (PRC) used an economy-wide, global computable general equilibrium model to simulate the scenarios of global agricultural productivity change induced by climate change up to 2080.

Implementations of the IAM/CGE approach require many assumptions about which effects to include, how each operates, and how they aggregate. Due to these shortfalls[27], it could mislead policy implementation if some underlying assumptions are not appropriate and more so when using such methodologies for the least developed countries like the current study undertakes.

3.2.2. The Ricardian and the Reduced Form Agronomic Methods

At the micro level, two[28] methods to finding the impact of climate change on crop revenue in general are discernible. First, Ricardian Method (RM)[29], 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

[27] The underlying assumptions of most of these models are of the advanced economies nature and mostly inappropriate for least developed countries such as West African cocoa producing countries.

[28] The two are Ricardian Crop Model and the Reduced form Agronomic Crop Model.

[29] $NR_i = a_0 + \sum (a_s T + b_s T_s^2 + c_s P_s + d_s P_s^2) + \sum f_c Z_c + e$ is usually the final estimable equation in many studies where T_s, P_s and Zc are respectively temperature, precipitation and economic variables.

for example, Molua and Cornelius, 2007[30], Kabubo-Mariara and Karanja, 2007[31], Kurukulasuriya and Mendelsohn, 2007,[32] and De, 2009)[33].

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 Neumann, 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, 2001). 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.

These two methods of study are of laboratory setting in nature and covers shorter periods which by definition do not adequately reflect the effects of climate change on perennial tree crops like cocoa. In other words, they are suitable for arable crops such as millet, maize, sorghum and so on.

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[30] Molua and Cornelius (2007) in Cameroon used the Ricardian cross-sectional approach.
[31] Kabubo-Mariara and Karanja (2007): in Kenyan Crop Agriculture used the Ricardian Method.
[32] A Ricardian analysis of the impact of climate change on African cropland was investigated by Kurukulasuriya and Mendelsohn (2007).
[33] De (2009) on agriculture in Zimbabwe also used the Ricardian approach and undertook sensitivity analysis based on the results from this approach.

3.2.3. Production Function and Hedonic Price Approach

Production function method relies on experimental evidence of the effect of temperature and precipitation on agricultural yields (Hall, 1998). The appealing feature of the experimental design is that it provides estimates of the effect of weather on the yields of specific crops that are purged of bias due to determinants of agricultural output that are beyond farmers' control (e.g., soil quality). This function is specified and the yields of different species of crops are examined under different climatic conditions (Reinsborough, 2003).The model assumes that the different species of crop do not have any means of adapting to the changing climate condition. It also assumes that land used in a given year for a specific crop will be used for that same crop in other years. It is straightforward to use the results of these experiments to estimate the impact of a given change in temperature or precipitation. Its disadvantage is that the experimental estimates are obtained in a laboratory setting as the RM and the RFCM and do not account for profit maximizing farmers' compensatory responses to changes in climate.

Mendelssohn, Nordhaus, and Shaw (MNS) proposed the hedonic approach as a solution to the production function's shortcomings (Mendelsohn, 1999). The hedonic method aims to measure the impact of climate change by directly estimating the effect of temperature and precipitation on the value of agricultural land. Its appeal is that if land markets are operating properly, prices will reflect the present discounted value of land rents into the infinite future. The limitation is that since at least the classic Hoch (1958 and 1962) and Mundlak (1961) studies, it has been recognized that unmeasured characteristics (example, soil quality) are an important determinant of output and land values in agricultural settings. Consequently, the hedonic approach may confound climate with other factors and the sign and magnitude of the resulting omitted variables bias is unknown. Also with this approach, unobserved variables such as irrigated water are likely to co-vary with climate. As cited in Oliver (2006), cross-sectional hedonic equations appear to be plagued by omitted variables bias in a variety of settings.

For some researchers[34] to overcome these problems they have tried to use random year-to-year variation in temperature and precipitation to estimate their effect on agricultural profits

[34] Deschenes and Greenstone (2006), used a county-level panel data file constructed from the Censuses of Agriculture to estimate the effect of weather on agricultural profits, conditional on county and state by year fixed effects.

to assess whether on average US farm profits are higher or lower in warmer and wetter years. To do this, they multiplied the estimated impact of temperature and precipitation on agricultural profits by the predicted change in climate to infer the economic impact. This variation is presumed to be orthogonal to unobserved determinants of agricultural profits, so it offers a possible solution to the omitted variables bias problems that appear to plague the hedonic approach. The primary limitation of the approach is that farmers cannot implement the full range of adaptations in response to a single year's weather realization. Consequently, its estimates of the impact of climate change may be biased downwards (Deschenes and Greenstone, 2006).

3.2.4. The Translog and Cobb-Douglas Functional Approach

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:

$$In(\frac{q}{q^{'}}) = \alpha_o + \sum_{i=1}^{n} \alpha_i \ln(\frac{x_i}{x_i^{'}}) + \frac{1}{2}\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} \beta_{ij} \ln(\frac{x_i}{x_i^{'}}) \ln(\frac{x_j}{x_j^{'}}) + \sum_{k+1}^{m} \gamma_k Z_k + \varepsilon_i \quad (19)$$

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[35] 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

[35] *Lau, L.J., 1986. Functional Forms in Econometric Model Building. Pp. 1515-1565. In: Griliches, Z., and Intriligator, M.D. (Eds.), Handbook of Econometrics, Volume III.*

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.

A feature of the translog production function is that in the case of a single output production function monotonicity requires positive marginal products with respect to all inputs and thus non-negative elasticities. With respect to the normalized translog production model the marginal product of input i is obtained by multiplying the logarithmic marginal product with the average product of input[36] i. Thus, empirically the normalised specification takes the form:

$$\frac{d(\frac{q}{q'})}{d(\frac{x_i}{x'})} = \frac{d(\frac{q}{q'})}{d(\frac{x_i}{x'})}\frac{d\ln(\frac{q}{q'})}{d\ln(\frac{x_i}{x'})} = \frac{d(\frac{q}{q'})}{d(\frac{x_i}{x'})}\left[\alpha_i + \sum_{j=1}^{n}\beta_{ij}\ln(\frac{x_i}{x'})\right] > 0 \tag{20}$$

Since both ($(\frac{q}{q'})$) and ($(\frac{x_i}{x_i'})$) are positive numbers, monotonicity depends on the sign of the term in parenthesis[37].

The translog function in the agronomic literature has also been used mostly on damage-abatement analysis. For example, Zhenfei (2005)[38] specified the translog function as:

$$\ln y = \left[c + \sum_{i=1}^{N-1}c_i + \sum_{t=91}^{99}d_t + \sum_{k=1}^{5}\alpha_k\ln(x_k) + \frac{1}{2}\sum_{k=1}^{5}\sum_{j=1}^{5}\alpha_{kj}\ln(x_k)\ln(x_j) + \gamma_0.R\right] - (\beta_0 + \beta_1 z + \beta_2 x_2 + \beta_3 x_3)^2 + \varepsilon \tag{21}$$

where α, β, γ, c and d were parameters to be estimated. The arguments x_k are productive input use, with $k = 1$ for land, 2 for labour, 3 for capital, 4 for fertilizer and 5 for exogenous inputs such as weather variables. Pesticides are denoted as z, which is aggregated over fungicides, herbicides and other pesticides. R is the percentage of major root crops (potatoes, sugar beets and onions) in the total area. This variable reflects the impact of differences in

[36] Thus the monotonicity condition given holds for translog with normalized specification.

[37] *If it is assumed that markets are competitive and factors of production are paid their marginal products, the term in parenthesis equals the input* $i's$ *share of total output,* s_i.

[38] Zhengfei, 2005. Econometric analysis of agricultural production: New primal perspectives Ph.D thesis Wageningen University – With summaries in English and Dutch

rotational system on production. Individual farm effects are captured by the farm dummy c_i. The subscript i indexes each farm and N is the number of farms. The year dummy d_t captures yield differences across years as agricultural production is subject to dramatic yield variations from year to year, mainly due to weather conditions. Finally, ε denotes disturbance terms representing factors that are not accounted for in the specification such as measurement errors and other stochastic events.

In most empirical studies separability is usually rejected because under certain circumstances there could be interactions, particularly the one between fertilizer and pesticides. Studies have shown that unhealthy crops may use water and nutrients less efficiently (see for example Spiertz, 1980; De Wit, 1992), suggesting positive interactions; on the other hand, fertilizer may contribute to weed growth and therefore decrease the effect of pesticide (example, herbicide), resulting in negative interactions. In such cases, the specification in the methodological literature takes the form:

$$\ln(y) = c + \sum_{i-1}^{N-1} c_i + \sum_{t=91}^{99} d_t + \delta.R + \sum_{k=1}^{3} \alpha_k \ln(x_k) + \frac{1}{2}\sum_{k=1}^{3}\sum_{j=1}^{3} \alpha_{kj} \ln(x_k)\ln(x_j) + \sum_{m=1}^{3} \beta_{om} \ln(z_m) + \frac{1}{2}\sum_{m=1}^{3}\sum_{q=1}^{3} \beta_{mq} \ln(z_m)\ln(z_q) +$$

$$\sum_{k=1}^{3}\sum_{m=1}^{3} \gamma_{km} \ln(x_k)\ln(z_m) - (\beta_0 + \beta_1 z_1 + \beta_2 z_2 + \beta_3 z_3)^2 + \varepsilon \qquad (22)$$

The translog part embedded in (22) is thought of as a generalized crop response model that allows for interactions between growth inputs and facilitating inputs[39]. Accommodating input asymmetry, this general framework usually provides more robust tests for separability or interactions.

In most panel study, the translog has been used to examine input substitution in crop yield (see Berndt and Christensen, 1973), Separability and aggregation[40], technical change and productivity growth[41] and productive efficiency (see for example, Green, 1980; Kalirajan,

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[39] See Zhengfei G, O Lansink, M Ittersum, A Wossink (2006): Integrating Agronomic Principles into Production Function Estimation: A Dichotomy of Growth Inputs and Facilitating Inputs, *American Journal of Agricultural Economics*, vol. 88, issue 2, pp. 32, Department of Agricultural and Resource Economics, North Carolina State University.
[40] See Danny and Fuss (1977).
[41] See May and Denny (1979).

1990). In panel data context, the assumption of time trend representation of technical change is considered non-neutral and scale augmenting[42]. In such cases the specification takes the form:

$$\ln y_{it} = \beta_0 + \sum_{j=1}^{j} \beta_j \ln x_{jit} + \frac{1}{2}\sum_{j=1}^{j}\sum_{k=1}^{j} \beta_{jk} \ln x_{jit} \ln x_{kit} + \gamma_1 t + \frac{1}{2}\gamma_2 t^2 + \sum_{j=1}^{j} \alpha_j \ln x_{jit} t \qquad (23)$$

Where $i = 1,2...,N$ are the cross section units; $t = 1,2...,T$ are the time periods; $j,k = 1,2,...,J$ are applied inputs; $\ln y_{it}$ is the logarithm of output of the i th individual in period t; $\ln x_{jit}$ is the logarithm of the j th input applied of the i th individual in period t; t is the time trend ; β, γ and α are usually the parameters estimated.

The Cobb-Douglas is another widely used functional form in agricultural crop yield analysis. It has been used in most cases to quantify the impact of different climatic and crop management scenarios on the yields of major crops such as irrigated rice, maize, and cocoa[43]. In agricultural crop yield analysis it is usually used as an augmented model of the form:

$$Y_{it} = \beta_0 + \sum_{m=1}^{n} \beta_{0m} D_{mit} + \sum_{k=1}^{l} \beta_k \ln(X_{kit}) + \varepsilon \qquad (24)$$

Where $\ln Y =$ is the natural log of the output, $i =$ is household index $(i = 1...,N)$, $t =$ time index (cropping season), $\beta =$ vector of parameters to be estimated, $D_m =$ vector of dummy variables, $\ln X_k =$ ln of input vectors including climatic related variables, and $\varepsilon = N(0,\sigma_\varepsilon)$ distributed random error term.

In the methodological literature apart from variables measuring the input of land, labour, and capital, the production functions contain climatic and hydrologic variables as additional input factors[44] again as natural logarithms. Several dummy variables usually used in such

[42] See baltagi and Griffin (1988).

[43] Keil et al (2007) used the Cobb-Douglas to quantify the mitigation of the impact of El Niño-related drought on smallholder farmers in Central Sulawesi, Indonesia: An interdisciplinary modeling approach combining linear programming with stochastic simulation.

[44] For example, the dependent variables are the natural logarithms of the reported yields of husked rice, dried maize seeds, and dried cocoa seeds in Keil et al 2007 study.

studies account for differences in important qualitative factors[45]. As noted by Keil (2004)[46]in his study , the production functions of maize and cocoa included variables measuring the amount of rainfall received during the cropping season/year in a given village; and explained that the squared term of the variable allows the partial production elasticity of rainfall to be non-constant and output to decline at very high precipitation levels. In the case of irrigated rice, the study included a variable measuring rainfall plus the calculated total discharge in the corresponding sub-catchment during the cropping season, the latter being a proxy of the amount of irrigation water available.

Battese (1997) discoursed that the weakness of the translog and Cob-Douglas in such farm studies is that in most cases no cash inputs are applied and such 'zero-observations' may lead to biased parameter estimates of the respective explanatory variables. To account for this some studies include dummy variables that take on the value of one in the case of a 'zero-observation' of the corresponding explanatory variable, and the value of zero otherwise.

3.2.5. Climate change and cocoa specific study methods

Specific studies on the impact of climate change on cocoa production are undeveloped 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.

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[45] Gunawan D, 2006. Atmospheric Variability in Sulawesi, Indonesia - Regional Atmospheric Model Results and Observations, a PhD thesis, Faculty of Forestry and Forest Ecology, Georg-August-University Gottingen, Germany.

[46] Keil A (2004), the socio-economic impact of ENSO-related drought on farm households in Central Sulawesi, Indonesia. Shaker Verlag, Aachen, Germany.

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 limitations of 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[47] 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

[47] A physiological growth and production model for cocoa (SUCROS-Cocoa) is based on the SUCROS-family of physiological crop growth models. It calculates light interception, photosynthesis, maintenance respiration, evapotranspiration, biomass production and bean yield for cocoa trees grown under shade trees. It can cope with both potential and water-limited situations, and is parameterized using existing information on cocoa physiology and morphology.

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)[48].

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 pod 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.

3.3. Empirical review

Thorough examination of the empirical literature on the impact of climate change on cocoa production shows that few studies have concentrated on this subject. However, the literature is rich on the impact of climate change on agriculture as a whole. The interest of most authors reveals the ascertainment of which climatic variable is significant in explaining the impact of climate on agricultural output or revenue as a whole. The results found in the literature have been grouped according to the findings that have been discovered in the literature.

3.3.1. Climate sensitivity to agriculture as a whole

A convenient starting point is the work on economic valuation of the impact of climate change on agriculture in Europe. Quiroga and Iglesias (2008), using global climate models and regional climate models, observed that uncertainty derived from socio-economic scenarios has a larger effect than the ones derived from climate scenarios. A literature review analysis using cross-sectional data on the topic-climate change and global agriculture: recent

[48] For a full documentation of the SUCROS-Cocoa (previously presented as ‘‘CASE2’’, version 2.2), see the technical program manual (Zuidema et al., 2003; earlier versions are described in Anten et al., 1993; Gerritsma and Wessel, 1999).

findings and issues, Reilly (1995) concluded that there are potential effects of climate change on global agriculture, but significant uncertainties remain.

The farming sector vulnerability to climate change and variability was assessed in South Africa by Gbetibouo and Ringler (2009). They developed a vulnerability index and compared vulnerability indicators across the nine provinces of the country and concluded that the regions' most vulnerability to climate change and variability also have a higher capacity to adapt to its effect.

Islam (1989) using an exhaustive panel dataset of the German agricultural sector evaluated the relationship between climate conditions and land prices in agriculture. The main advantage of hedonic approach was the basis of consideration of the full range of adaptation options to the climatic environment. A Box-Cox form was employed to allow for very flexible relationships between land prices, warmth, moisture, and different socioeconomic variables. In a second step, the estimated results were used to forecast the impact of global climate change on the farming sector. The results were that a change of the temperature level has stronger impact than a change of rainfall. Using a greenhouse warming scenario, German farmers are expected to be winners of climate change at least in the short run. Maximum gains are estimated with a temperature increase of +1.0°C against the current levels. Should the temperature increase surpass 1.8°C, however, the impact on the farming sector will clearly be negative.

Assessing environment in agriculture in Sub-Saharan Africa using a time series data, Kofi-Tessio and Homevor, (2006), concluded that there is interrelation between agriculture and environment which is widely recognized by scientists, but agricultural economists despite their strategic position have not played an active role, through investigations, in bringing to the front the strong linkages. The authors reported that agriculture is central to the economic growth of this region and depends largely on natural resources which are under serious threat due to climate change.

Schoengold and Tadess (2009) in their study combined panel data techniques with spatial analysis to measure the impact of extreme weather events on the adoption of conservation tillage. Zellner's seemingly unrelated regression (SUR) technique was extended to spatial panel data to correct for cross-sectional heterogeneity, spatial autocorrelation, and contemporaneous correlation (Harding, 2007). They found that extremely dry conditions in recent years increase the adoption of other conservation tillage practices, while spring floods in the year of production reduce the use of no-till practices.

The assessment of climate change impact on smallholder and subsistence agriculture in the tropics by Morton (2007) concluded that smallholder and subsistence farmers will suffer impacts of climate change that will be locally specific and hard to predict. He observed that, the variety of crop and livestock species produced by any one household and their interactions, and the importance of nonmarket relations in production and marketing, will increase the complexity both of the impact and of subsequent adaptation, relative to commercial farms with more restricted ranges of crops. Small farm sizes, low technology, low capitalization, and diverse non-climate stressors will tend to increase vulnerability, but the resilience factors—family labour, existing patterns of diversification away from agriculture, and possession of a store of indigenous knowledge—should not be underestimated. That, "social-scientific study of the future impact of climate change on poor rural people in developing countries has tended to be concerned with the increased frequency of extreme events with generalized impacts" (Ibid). This is understandable given the short to medium term importance of extreme events, and the difficulties of predicting any trends, climate-related or otherwise, in the longer term (Hickman, 1973). He however, believes that there must also be a genuinely interdisciplinary attempt to apply the rapidly growing scientific knowledge of the effects of climate change on crops and livestock to the ''complex, diverse and risk-prone'' farming systems of developing countries. This will not only improve knowledge of impact, but just as important, aid in building adaptive capacity at all levels including that of farmers themselves.

A study on US agricultural land which estimated the effect of the presumably random year-to-year variation in temperature and precipitation on agricultural profits was undertaken by Gockowski (2004). Using long-run climate change predictions from the Hadley 2 Model, the preferred estimates indicated that climate change will lead to a $1.1 billion or 3.4%

increase in annual profits of US farmers. The analysis indicated that the predicted increases in temperature and precipitation will have virtually no effect on yields among the most important crops.

3.3. 2. Significance of temperature

A research on the effect of climate change on cocoa yield in the Cocoa Research Institute of Nigeria (CRIN) farm, Ibadan by Ajewole *et al* (2010) concluded that while there is weak inverse correlation in rainfall, positive weak correlation (0.2196) was established for temperature on yield.

In using macro data to estimate the influence of temperature and precipitation on economic activity in a country specific good including agricultural produce over several countries, Dell *et al* (2008) found temperature as having positive impact on economic activity (exports of agricultural produce) for both less developed and developed nations but precipitation was insignificant across the world. Jones *et al* (2010), in a regression on the growth rate of export produce on temperature and precipitation for several countries in the world arrived at the same conclusion.

3.3.3. Significance of precipitation

On the vulnerability and adaptation of climate change on cocoa in the semi-deciduous forest and evergreen rainforest zones, Anim-Kwapong *et al* (2004) in their study concluded that cocoa is highly sensitive to drought in terms of growth and yield. They recommended that it is reasonable to anticipate consistent decreases in projected output from 2020 to 2080.

The study on the actual impact of rainfall variability on agricultural production, with focus on the dry land cropping in Victorian regions during the period 1982-83 to 2004-05 Jamet et al (2009) concluded that dry land cropping in Victoria is sensitive to rainfall variability, but not to the inter-annual variability of average maximum temperature. According to the study, rainfall plays a more significant role to agricultural production than other farm inputs. They also identified that cereal production appears to be less sensitive to rainfall fluctuations than other crop production.

3.3.4. Significance of both temperature and precipitation

An evaluation of the effect of climate changes on cocoa production in Nigeria by Lawal *et al* (2007) concluded that a combination of optimal temperature, minimal rainfall and relative humidity will give a better yield and reduce disease incidence.

A study on the effects of climate change on cocoa production and vulnerability assessment; focusing on seedling mortality, production and processing of cocoa in Nigeria by Oyekale *et al* (2009), found that rainfall, temperature and sunshine are the most important climatic factors that affect cocoa production. Also, in Zimbabwe a study on economic impact of climate change using a cross sectional approach to measure net revenue from agriculture yield by De (2009) found that it is very sensitive to agriculture. The result was, however, not specific to temperature or precipitation but that climate variables impacted on agricultural yields.

Moreover, in their study conducted on economic impact of climate change in Cameroun Molua *et al* (2007) using the Ricardian cross-sectional approach found that net revenues fall as precipitation decreases or temperatures increase across all the surveyed farms. Also, economic impact of climate change on Kenyan crop agriculture by Kabubo-Mariara *et al* (2007), using the Ricardian Method, found that farmers in Kenya are aware of short term climate change impact and that most of them have noticed an increase in temperature, decline in precipitation thereby using adaptive methods.

A Ricardian analysis of the impact of climate change on African cropland was investigated by Kurukulasuriya and Mendelsohn (2007) and concluded that climate scenarios predict different temperature and precipitation changes in each country. This result is akin to De (2009) on economic impacts of climate change on agriculture in Zimbabwe where the use of the Ricardian approach found in their sensitivity analysis that, agricultural production in Zimbabwe's small holder farming system is significantly constrained by climatic factors, namely temperature and precipitation. Harding and Devisscher (2009) in their study of Kenya, Rwanda and Burundi using scientific data of temperature and precipitation for simulation concluded that Kenya in the region suffers from a twin problem of cyclic droughts and flood. Climate change is expected to exacerbate it. In Malawi, the factors that influence the productivity of maize among smallholder farmers were analyzed by Saur et al (2006) using the normalized translog production function and recognized the importance of both temperature and precipitation in the production process.

On weather effects on European Agriculture, Solomou and Wu (1999) concluded that weather shocks had significant effects on agricultural output over the pre-1913 period. The effects were noted as non-linear and accounted for approximately one third to two thirds of variations in agricultural production. The effect range of weather shocks were largest in Britain, partly reflecting the wider range of weather variations and the high share of crop production in the early part of the sample period. Also, assessing the impact of climate change on European agriculture, Zhengfei et al (2006) based on translog model, concluded that the effects of weather on agricultural was significant and could be a major challenge in the future. In quantifying the mitigation of the impact of El Niño-related drought on smallholder farmers in Central Sulawesi, Keil (2007) noted that both temperature and rainfall have serious impact on crop growth in Indonesia.

The synthesis of the empirical literature is that climatic variables have impact on crop yield as a whole but the depth of impact and significance of each variable depends on the region and the type of crops being investigated.

CHAPTER FOUR

THEORETICAL FRAMEWORK AND METHODOLOGY

This chapter employs agronomic ideas in deriving a-four input translog function as the theoretical framework for the study in a panel setting to examine the impact of climate change on cocoa production in West Africa. For the purposes of policy and the issue of possible omitted variables, a time series country model is derived in which Error Correction Mechanism is used to tie the short run to the long run relationship between cocoa output and the climatic variables for some selected countries within the region. The first section justifies the use of such method. The second and the third sections specify the model and expound the estimation procedure and techniques respectively. The last section explains the data sources and how they have been used in the estimation process.

4.1. Theoretical framework

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.

The translog function (Christensen, Jorgenson, and Lau, 1973) has become an integral tool for analyzing the production structure of many firms and industries across time. The choice of this function over the Cobb-Douglas (CD) and Constant Elasticity of Substitution (CES) is because it is conceptually simple and imposes no a priori restrictions on elasticities of substitution and returns to scale; hence its wide use in empirical analysis especially where the study requires an implicit assumption that nothing is known about the production process.

Cited in Christensen, Jorgenson and Lau (1973), imposing a priori restrictions such as homotheticity, homogeneity or separability on the production structure are not palatable and should rather remain a testable hypothesis within the estimation framework.

The translog function is generally viewed as a second order Taylor approximation to an arbitrary production form (Heathfield and Wibe, 1987), and does cover a wide variety of production functions, the reason why the translog function is gaining increased attention and is widely employed in Agricultural production where several inputs are needed in the specification process than the traditional labour and capital inputs alone.

The study is guided by the ideas of Fuss et al (1998) who asserted that ". . . a wide variety of compatible functional forms will usually be available," and they list five criteria for choosing a single form which are:

- Parsimony in parameters: Excess parameters exacerbate multicollinearity problems and, in small samples, seriously reduce error degrees of freedom.
- Ease of interpretation**:** Prefer a form in which parameters have an intrinsic and intuitive economic interpretation and in which functional structure is clear.
- Computational ease**:** Although nonlinear forms are feasible, linear-in-parameters systems have less expensive computations and more fully developed statistical theory.
- Interpolative robustness**:** The chosen functional form should be consistent with maintained hypotheses in the range of the data.
- Extrapolative robustness**:** The chosen functional form should be consistent with maintained hypotheses outside the range of the data.

4.1.1. The panel model specification

The agronomic field production literature recognizes two types of inputs, namely, growth inputs and facilitating inputs (Leontief 2007; Chambers and Lichtenberg 1990, 1996). According to Guan (2006) growth inputs are defined as those that are directly involved in biological process of crop growth and thus essential for crop growth such as seed type, nutrients, and water. Growth inputs determine attainable yield level in a given biophysical environment, assuming no yield reducing factors for maximum yield such as weeds, diseases, and pests. In line with this growth agronomic literature, three distinct yield levels are described: potential, attainable, and actual. These levels are determined by different growth conditions via growth defining, growth limiting, and growth reducing factors. Growth defining factors such as weather and species characteristics determine the potential yield, assuming that there are no growth limiting and reducing factors.

Facilitating inputs on the other hand are defined as those that are not directly involved in the basic biological process, but can help create or alter growth conditions under which growth inputs take effect (Guan et al, 2006). In this study, the growth inputs recognized for cocoa production are temperature which act on the physiology of the tree and precipitation, which operates on the rooting system of the tree, holding for species characteristics with the assumption that there are no growth limiting and reducing factors. In line with the background of the study, the facilitating inputs are hereby recognized as Labour and Capital (in the form of Fertilizer rather than machines). Cocoa output for the West African region is, therefore, characterized as a function of these growth and facilitating inputs:

$$Y = f(x_i) \tag{25}$$

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:

$$x_i = (L_{it}, K_{it}, T_{it}, P_{it}) \tag{26}$$

Where: $L_{it} =$ refers to labour input to the production of cocoa in country i and in time t (Effective labour in Agric is used in the respective countries). Owing to the fact that there is no specific information on labour in cocoa production for the various countries, it became necessary to use effective labour in Agriculture. For example, see Morton (2007).

$K_{it} =$ refers to Capital input to the production of cocoa (Fertilizer import for cocoa is used as a proxy). Fertilizer import is used while holding for insecticides, herbicides and so on because it is not easy to identify which chemicals go into cocoa production and which go into other crops. In this regard, the study uses specific data on fertilizer used for cocoa as a proxy namely, NPK. One therefore holds the assumption that there are no growth limiting and reducing factors.

$T_{it} =$ refers to an exogenous temperature growth input for cocoa growth in country i and in time t. As stated earlier, temperature acts on the physiology of the cocoa tree which could increase or reduce its growth.

P_{it} = refers to an exogenous precipitation growth input for cocoa production in country i and in time t. Precipitation acts on the rooting system of the cocoa tree which can improve or reduce growth of the tree.

By substituting equation (26) into (25) gives equation (27) as:

$$Y_{it} = f(L_{it}, K_{it}, T_{it}, P_{it}) \tag{27}$$

The general translog functional formula is presented as equation (28):

$$InY = \alpha + \sum \beta_i Inx_i + \sum_i \sum_j \delta_{ij}(Inx_i)(Inx_j) \tag{28}$$

$\delta_{ij} = \delta_{ji}$ for all i, j.

In line with the agronomic literature, the general formula of equation (28) can be modified to include some square terms. Such terms track the severity of impact of the regressors on the regressand.

$$InY = \alpha + \sum \beta_i Inx_i + \sum_i \sum_j \delta_{ij}(Inx_i)(Inx_j) + \sum_{i=1}^{k} \phi_i (\ln x_i)^2 + \sum_{j=1}^{k} \varphi_j (\ln x_j)^2 \tag{29}$$

Following from (29) the four inputs, aggregate translog production function can therefore be derived as:

$$InY_{it} = InA + \alpha_L{}^* In(L_{it}) + \alpha_K{}^* In(K_{it}) + \alpha_T{}^* In(T_{it}) + \alpha_p{}^* In(P_{it}) + \beta_{LL}{}^* In(L_{it})^* In(L_{it}) +$$

$$\beta_{KK}{}^{*}In(K_{it})^{*}In(K_{it})+\beta_{TT}{}^{*}In(T_{it})^{*}In(T_{it})+\beta_{PP}{}^{*}In(P_{it})^{*}In(P_{it})+\gamma_{LK}{}^{*}In(L_{it})^{*}In(K_{it})+\gamma_{LT}{}^{*}In(L_{it})^{*}In(T_{it})+$$

$$\gamma_{LP}{}^{*}In(L_{it})^{*}In(P_{it})+\gamma_{KT}{}^{*}In(K_{it})^{*}In(T_{it})+\theta_{KP}{}^{*}In(K_{it})^{*}In(P_{it})+\theta_{KL}{}^{*}In(K_{it})^{*}In(L_{it})+$$

(30)

$$\psi_{TL}{}^{*}In(T_{it})^{*}In(L_{it})+\psi_{TK}{}^{*}In(T_{it})^{*}In(K_{it})+\psi_{TP}{}^{*}In(T_{it})^{*}In(P_{it})+\psi_{PL}{}^{*}In(P_{it})^{*}In(L_{it})+$$

$$\eta_{PK}{}^{*}In(P_{it})^{*}In(K_{it})+\eta_{PT}{}^{*}In(P_{it})^{*}In(T_{it})=f(L_{it},K_{it},T_{it},P_{it})$$

To avoid multicollinearity among the variables, there is the need to invoke the six (6) cross-equation symmetry conditions on (30) as:

$$\gamma_{LK}=\theta_{KL};\gamma_{LT}=\gamma_{TL};\gamma_{LP}=\gamma_{PL};\gamma_{KT}=\psi_{TK};$$
$$\theta_{KP}=\eta_{PK};\psi_{TP}=\eta_{PT} \qquad (31)$$

Therefore, equation (30) reduces from 20 variables to 14 variables as:

$$InY_{it}=InA+\alpha_{L}{}^{*}In(L_{it})+\alpha_{K}{}^{*}In(K_{it})+\alpha_{T}{}^{*}In(T_{it})+\alpha_{P}{}^{*}In(P_{it})+\beta_{LL}{}^{*}In(L_{it})^{*}In(L_{it})+$$

$$\beta_{KK}{}^{*}(K_{it})^{*}In(K_{it})+\beta_{TT}{}^{*}In(T_{it})^{*}In(T_{it})+\beta_{PP}{}^{*}In(P_{it})^{*}In(P_{it})+\gamma_{LK}{}^{*}In(L_{it})^{*}In(K_{it})+\gamma_{LT}{}^{*}In(L_{it})^{*}In(T_{it})+$$

$$\gamma_{LP}{}^{*}In(L_{it})^{*}In(P_{it})+\gamma_{KT}{}^{*}In(K_{it})^{*}In(T_{it})+\theta_{KP}{}^{*}In(K_{it})^{*}In(P_{it})+\theta_{TP}{}^{*}In(T_{it})^{*}In(P_{it}) \qquad (32)$$

Further, simplifying and re-arranging (32) yields equation (33) as:

$$InY_{it}=InA+\alpha_{L}InL_{it}+\alpha_{K}InK_{it}+\alpha_{T}InT_{it}+\alpha_{P}InP_{it}+\tfrac{1}{2}\beta_{LL}In(L_{it})^{2}+\tfrac{1}{2}\beta_{KK}In(K_{it})^{2}+\tfrac{1}{2}\beta_{TT}In(T_{it})^{2}+\tfrac{1}{2}\beta_{PP}In(P_{it})^{2}+$$
$$\gamma_{LK}InL_{it}InK_{it}+\gamma_{LT}InL_{it}InT_{it}+\gamma_{LP}InL_{it}InP_{it}+\gamma_{KT}InK_{it}InT_{it}+\theta_{KP}InK_{it}InP_{it}+\theta_{TP}InT_{it}InP_{it} \qquad (33)$$

The agronomic literature (Guan, 2006) 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 (33) leads to equation (34)[49]:

$$InY_{it} = InA + \alpha_L InL_{it} + \alpha_K InK_{it} + \alpha_T InT_{it-p} + \alpha_P InP_{it-p} + \tfrac{1}{2}\beta_{LL} In(L_{it})^2 + \tfrac{1}{2}\beta_{KK} In(K_{it})^2 + \tfrac{1}{2}\beta_{tt} In(T_{it-p})^2 + \tfrac{1}{2}\beta_{PP} In(P_{it-p})^2 +$$

$$\gamma_{LK} InL_{it} InK_{it} + \gamma_{LT} InL_{it} InT_{it-p} + \gamma_{LP} InL_{it} InP_{it-p} + \gamma_{KT} InK_{it} InT_{it-p} + \theta_{KP} InK_{it} InP_{it-p} + \theta_{TP} InT_{it-p} InP_{it-p} + \varepsilon_t \qquad (34)$$

4.1.2. The time series model specification

Economic theory often suggests that certain groups of economic variables should be linked by a long-run equilibrium relationship. Although the variables may drift away from equilibrium for a while, economic forces may be expected to act so as to restore equilibrium. Following from this and for the fact that country specific studies are relevant for policy purposes and to address the dynamics of short run climatic variables to the long run output of cocoa, it was imperative to specify a time series model for such estimation. Just as in the preceding equations, the country specific growth and facilitating inputs hold as:

$$Y_t = f(L_t, K_t, T_t, P_t) \qquad (35)$$

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

Upon the ideas of equation 27 and 28, the time series aggregate translog function can be derived as equation 36:

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

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

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

(36)

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[49] Though a fully grown cocoa tree cannot be expected till ten years, it starts yielding its fruits from five years. The assumption here, therefore, is that five years impact of climatic variables would have been fully felt by the tree.

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

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

By invoking the six (6) cross-equation symmetry conditions on (36) as:

$$\gamma_{LK}=\theta_{KL};\gamma_{LT}=\gamma_{TL};\gamma_{LP}=\gamma_{PL};\gamma_{KT}=\psi_{TK};$$
$$\theta_{KP}=\eta_{PK};\psi_{TP}=\eta_{PT} \tag{37}$$

Hence, equation (36) reduces from 20 variables to 14 variables as:

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

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

$$\gamma_{LP}{}^{*}In(L_t)^{*}In(P_t)+\gamma_{KT}{}^{*}In(K_t)^{*}In(T_t)+\theta_{KP}{}^{*}In(K_t)^{*}In(P_t)+\theta_{TP}{}^{*}In(T_t)^{*}In(P_t) \tag{38}$$

By simplifying and re-arranging (38) yields equation (39) as:

$$InY_t=InA+\alpha_L InL_t+\alpha_K InK_t+\alpha_T InT_t+\alpha_P InP_t+\tfrac{1}{2}\beta_{LL}In(L_t)^2+\tfrac{1}{2}\beta_{KK}In(K_t)^2+\tfrac{1}{2}\beta_{TT}In(T_t)^2+\tfrac{1}{2}\beta_{PP}In(P_t)^2+$$
$$\gamma_{LK}InL_tInK_t+\gamma_{LT}InL_tInT_t+\gamma_{LP}InL_tInP_t+\gamma_{KT}InK_tInT_t+\theta_{KP}InK_tInP_t+\theta_{TP}InT_tInP_t \tag{39}$$

In introducing standard distributed lags on the climate variables yields equation (40) as:

$$InY_t=InA+\alpha_L InL_t+\alpha_K InK_t+\alpha_T InT_{t-p}+\alpha_P InP_{t-p}+\tfrac{1}{2}\beta_{LL}In(L_t)^2+\tfrac{1}{2}\beta_{KK}In(K_t)^2+\tfrac{1}{2}\beta_{tt}In(T_{t-p})^2+\tfrac{1}{2}\beta_{PP}In(P_{t-p})^2+$$
$$\gamma_{LK}InL_tInK_t+\gamma_{LT}InL_tInT_{t-p}+\gamma_{LP}InL_tInP_{t-p}+\gamma_{KT}InK_tInT_{t-p}+\theta_{KP}InK_tInP_{t-p}+\theta_{TP}InT_{t-p}InP_{t-p}+\varepsilon_t \tag{40}$$

4.2. Estimation procedure and technique

To estimate for the impact of Climate Change on cocoa production in West Africa, equation (34) is estimated in a panel setting. The time series country specific study requires the estimation of equation (40).

4.2.1. Procedure and technique for the panel estimation

In terms of the panel estimation of (34), it is crucial to note that the combination of time series with cross-sections can enhance the quality and quantity of data in ways that would be impossible using only one of these two dimensions (Gujarati, 2009: 638). Panel technique allows one to control for variables that cannot be observed or measured such as cultural factors (when comparing countries) or difference in business practices across firms. It also helps to control for unobservable variables that change over time, but not across entities such as national policies and international agreements. With panel data, one can include variables at different levels of analysis suitable for multilevel or hierarchical modeling.

The quandary of using random or fixed effect model in empirical study of this nature was of much importance. The Hausman specification test is the classical test of whether the fixed or random effects model should be used (see Green, 2008). The research question is whether there is significant correlation between the unobserved person-specific random effects and the regressors. If there is no such correlation, then the random effects model is deemed more powerful and parsimonious. If there is such a correlation, the random effects model would be inconsistently estimated and the fixed effects model would be the model of choice. In instances where the result is inconclusive, a further test using the Breusc2-Pagan Lagrange Multiplier (LM) Test is performed. The null hypothesis in the LM test is that variances across entities are zero. That is, no significant difference exists across units. If the results fail to reject the null hypothesis then the conclusion is that random effect model is not appropriate. That is, no significant differences across countries are found, given the data set therefore, fixed effects would be used.

After the Hausman test was inconclusive, the Breusch-Pagan Multiplier Test was performed and since the study failed to reject the null hypothesis it became relevant to use the fixed effect model for estimation and interpretation of the results. See the results of both the Hausman and Breusch-Pagan Lagrange Multiplier Test at Appendix A.

The fixed effect model developed by Mundlak (1961); Wallace and Hussein (1969) frequently have too many cross-sectional units of observations which may sap the model of sufficient number of degrees of freedom thereby reducing its adequacy of powerful statistical tests. To overcome this difficulty, this study considered the fact that the cross-sectional component is small, but with several variables, necessitating for a correlation analysis. The highly correlated variables were dropped from the estimation to strengthen the predictive power of the model.

A major advantage of the fixed effects model is that the error terms may be correlated with the individual effects. If group effects are uncorrelated with the group means of the regressors, it would probably be better to employ a more parsimonious parameterization of the panel model.

With regard to the second specific objective, a simulation on the real values of equation (34) using various scientific reports as a guide for the creation of unpleasant scenarios was explored. At this point, an in-sample simulation was undertaken which gave the strength of the model by comparing the actual to the baseline model using Gauss-Siedel as the solver in a Dynamic-Deterministic Simulation.

In doing this, the scenarios were considered based on the projections of the following reports; namely, IPCC (2007), UNDP (2007/8) reports for temperature and precipitation. Below are their reference projections:

- UNDP (2007/8) report projects temperature for this region to be 0.2ºC per every decade. This implies an approximate 0.02 per year is the expectation.
- IPCC (2007) report states temperature would be within the range of 3- 4ºC by 2080/2099. That, precipitation for the African region will be reduced by 15-20% within the next century.
- IPCC (AR 4) reports that temperature in Africa has already been risen by 1ºC and projection for 2050 is to exceed 3ºC, that is, 43 years of projection.

Based on these facts, a more plausible and heroic assumptions were arrived by using the extreme projections to compute for annual likely increase in temperature and reduction in precipitation. The values arrived at in log terms (since the model was based on log values) were used for simulation with various combinations[50] of temperature and precipitation. Suffice it to say that 2009 values for cocoa, temperature and precipitation were used as the base line situation and using the final values of the estimated model[51] of equation 24 to undertake the simulation. The estimated equation is:

$$Y = 0.9235 + (0.477 * L) + (0.2129 * K) - (0.572 * T) + (0.521 * P) - (0.201 * LP) - (0.464 * KT) - (0.685 * T_{(-3)}) + (0.932 * P_{(-1)}) \quad (41)$$

[50] They include: a) Rise in temperature b) fall in precipitation c) fall in temperature d) rise in precipitation e) combinations of a, b, c, d.

[51] It is important to stress that some variables were dropped from equation 24 after the correlation analysis because they were highly correlated above .80.

4.2.2. Procedure and technique for the time series estimation

Various approaches have been used in the literature when it comes to empirical modeling and estimation of time series production function depending on the objectives at hand. The model used for this estimation is equation (40) of the translog functional form, which is estimated in time series method. 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. Dickey and Fuller (1979, 1980) formally devised a procedure to test for non-stationary through existence of the lagged dependent variable. If the DF statistical value is smaller than the critical value, then the null hypothesis is rejected- implying there is "Non-cointegration". That is, thus the DF t-test of H0: $\Phi = 1$ against H1: $\Phi < 1$. Strictly, this is the test of no-cointegration, because the null of unit root implies that there is no-cointegration between the dependent and the regressors. So if the H0: $\Phi = 1$ is rejected then, the conclusion is that there is a cointegration and vice versa.

Cointegration means that long-run equilibrium relationship exists among the non-stationary variables[52]. 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)[53]. The inclusion of ECT in a model ensures that the long run relationship is preserved. One of the most important results in cointegration analysis is the

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[52] *If a group of variables is cointegrated, they must obey an equilibrium relationship in the long run, although they may diverge substantially from equilibrium in the short run.*

[53] *Here the long-run relationship measures any relation between the levels of the variables under consideration while the short-run dynamics measure any dynamic adjustments between the first differences of the variables.*

Granger representation theorem (Granger 1983, Engle and Granger 1987), which states that if a set of variables are cointegrated of order 1, 1[CI(1,1)], then, there exists a valid error correction representation of the data. In this study, when the series were subjected to Unit root test using both Augmented Dickey-Fuller and Phillips-Perron, the results indicated that all the variables estimated were not stationary at levels implying there was the existence of Unit root. However, they were all stationary at first difference. The equation for the ECM was then specified as:

$$InY_t = InA + \Psi(lp)\alpha_L InL_t + \Psi(lp)\alpha_K InK_t + \Psi(lp)\alpha_T InT_{t-p} + \Psi(lp)\alpha_P InP_{t-p} + \Psi(lp)\tfrac{1}{2}\beta_{LL} In(L_t)^2 +$$
$$\Psi(lp)\tfrac{1}{2}\beta_{KK} In(K_t)^2 + \Psi(lp)\tfrac{1}{2}\beta_{tt} In(T_{t-p})^2 + \Psi(lp)\tfrac{1}{2}\beta_{PP} In(P_{t-p})^2 + \Psi(lp)\gamma_{LK} InL_t InK_t + \Psi(lp)\gamma_{LT} InL_t InT_{t-p} +$$
$$\Psi(lp)\gamma_{LP} InL_t InP_{t-p} + \Psi(lp)\gamma_{KT} InK_t InT_{t-p} + \Psi(lp)\theta_{KP} InK_t InP_{t-p} + \Psi(lp)\theta_{TP} InT_{t-p} InP_{t-p} + \varepsilon_t \qquad (42)$$

where Ψ (lp) =log operator of order p & optimal p is selected using Akaike and Schwarz Information Criteria.

Consequently, cocoa output as the dependent variable was regressed against labour, capital, temperature, precipitation and against some of their lag terms as well as their square terms.

Although Engle *et al's* (1987) two-step error-correction model as expatiated was used in a multivariate context; the VECM is hereby also used for comparison due to the fact that it yields more efficient estimators of cointegrating vectors. The VECM is a full information maximum likelihood estimation model, which allows for testing for cointegration in a whole system of equations in one step and without requiring a specific variable to be normalized. This allows the avoidance of carrying over the errors from the first step into the second, in the case of the methodology used in Engle et al, (1987). It also has the advantage of not requiring a priori assumptions of endogeneity or exogeneity of the variables. The VECM is of the form:

$$\Delta Y_t = \sum_{j=1}^{k-1} \Gamma_j \Delta Y_{t-j} + \alpha\beta' Y_{t-k} + \mu + \varepsilon_t \qquad (43)$$

Where $\sum_{j=1}^{k-1} \Gamma_j \Delta Y_{t-j}$ and $\alpha\beta' Y_{t-k}$ are the vector autoregressive (VAR) component in first differences and error-correction components, respectively, in levels of Eq. (42). Y_t is a *p* x 1 vector of variables and is integrated of order one. μ is a *p* x 1 vector of constants. *k* is a lag structure, while ε_t is a *p* x 1 vector of white noise error terms. Γ_t is a *p* x *p* matrix that represents short-term adjustments among variables across *p* equations at the *j*th lag. β' is a *p* x *r* matrix of cointegrating vectors, and Δ denotes first differences. α is a *p* x *r* matrix of speed of adjustment parameters representing the speed of error correction mechanism. A larger α suggests a faster convergence toward long-run equilibrium in cases of short-run deviations from this equilibrium. In estimating the VECM, the study first checked for stationarity and unit roots through performing the augmented Dickey-Fuller (ADF) and Phillips-Peron (PP) tests on the variables in levels and first differences as was done for the preceding approach. Only variables integrated of the same order were established as cointegrated, and the unit roots tests helped in the determination of which variables are integrated of order one, or I (1).

The choice of lag lengths was decided, for simplicity in this study by the multivariate forms of the Akaike information criterion (AIC) and Schwartz Bayesian criterion (SBC), where AIC = *T* ln(residual sum of squares) + 2*n* and SBC = *T* ln(residual sum of squares) + ln(*T*). The AIC and SBC are model selection criteria developed for maximum likelihood estimation techniques. In minimizing the AIC and SBC, the implication is that there is a minimization of the natural logarithm of the residual sum of squares adjusted for sample size, *T*, and the number of parameters included, *n*. In such a case, the model is theoretically estimated by regressing the ΔY_t matrix against the lagged differences of ΔY_t and Y_{t-k} and determines the rank of $\pi = \alpha\beta'$. The eigenvectors in β' are estimated from the canonical correlation of the set of residuals from the regression equations. To determine the rank of π, which gives the order of cointegration, *r*, this method or procedure calculates the characteristic roots or eigen values of π, $\hat{\lambda}_i$. Furthermore, it became relevant to test for *r* using the λ_{trace} and $\lambda_{\max}$ test statistics, where $\lambda_{trace} = -T\sum_{i=r+1}^{p}\ln(1-\hat{\lambda}_I)$ and $\lambda_{\max} = -T\sum_{i=r+1}^{p}\ln(1-\hat{\lambda}_{r=1})$. The choice of the number of maximum cointegrating relationships was based on the λ_{trace} tests. The $\lambda_{\max}$ test was used to test specific alternative hypotheses. The study rejects models where p has a full rank since in such a situation Y_t is stationary and has no unit root, and so there would be no error correction.

With regard to the background of the study, the climatic variables have a trend and, consequently, the study test for cointegration choosing the appropriate deterministic trend assumption. Specifically, the study chooses the existence of an intercept and trend in the long run relationship and a linear trend in the short-run relationship.

Finding supporting the existence of a cointegrating relationship among the variables, a VECM was estimated. A VEC Model is a restricted VAR which has cointegration relations built into the specification so that it restricts the long-run behavior of the endogenous variables to converge to their cointegrating relationships while allowing for short-run adjustment dynamics. The cointegration term is known as the correction term since the deviation from long-run equilibrium is gradually corrected through a series of partial short-run adjustments. By assumption, if π did not have a full rank and rather have multiple cointegrating vectors, the option is choosing the first eigenvector based on the largest eigen value, which is probably the most useful.

4.3. Data Requirement and Sources

Temperature and Precipitation data were sourced from the FAOSTAT for selected cocoa producing areas across 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.

Temperature figures acquired are aggregate level country data from the FAOSTAT. At this site, respective countries have their data on meteorological stations listed where both daily, monthly and aggregate annual data are recorded. Since this study is on perennial tree crops, it was necessary to consider annual data as opposed to quarterly data which is rather suitable for arable crops. This study submits that the dilemma of which station to choose and to represent the entire country was overcome by a cursory survey of each country to identify the areas where cocoa is dominantly produced as a proxy for the rest of the cocoa producing areas for that specific country. For example, in Ghana, stations from the Western region (Sefwei Yiawso) were preferred to Goaso in the Brong Ahafo Region, though they all produce cocoa. Likewise, in Nigeria, stations from Ekiti and Edo were preferred to stations from Cross River and Enugu states.

Precipitation data was also of the aggregate annual type and followed the same criteria as that of the temperature. Any station that was selected for the temperature data was also automatically used for precipitation data source. In this vein, maximum, minimum and mean precipitation data were all sourced for the data analysis.

Cocoa Production (output) data were equally sourced from the FAOSTAT. At this site, one can find several cocoa products such as processed, semi processed, chocolate and cocoa butter as well as volume of cocoa raw beans produced as annual production data. This study used the annual production data on cocoa beans in metric tonnes.

Fertilizer import data were also sourced from FAOSTAT data base. In this regard, several varieties of chemical imported to the specific country are available and recorded at the site. Varieties of fertilizers are also listed in this site but this study considered the NPK imported for the countries under study. From the agronomic literature, NPK is mostly used for cocoa production than any other fertilizer and so the study deemed it necessary a better proxy for capital.

Data on active population in agriculture as a proxy for Labour input was sourced from the African Development Indicators (ADI). Listed on this site are population of various occupation and since there is no specific data for cocoa producers, it was very appropriate that active population in agriculture is used as a proxy for labour in cocoa production for the respective countries under study.

CHAPTER FIVE

PRESENTATION AND DISCUSSION OF EMPIRICAL RESULTS

This section presents the empirical results and a discussion of its outcome. The first covers a correlation analysis of the climatic variables used in this study and cocoa output. The second section deals with the panel results from the separate use of mean and maximum datasets of climatic variables. The simulation results addressing various temperature and precipitation scenarios are covered in the third section. The fourth section reflects the time series results of mean and maximum values of the two climatic variables and how they impact on cocoa output in the selected countries, namely; Nigeria, Ghana and Cote D'lvoire. The final section discuses the result of the various estimations.

5.1. Correlation analysis of cocoa output and the two climatic variables.

Tables 4 and 5 report the correlation analysis of the eight cocoa producing countries in West Africa. Table 4 uses the mean climatic values whereas table 5 uses the maximum 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 data set for the cocoa producing areas in the specific countries under study. While table 4 shows separate data sets for both cocoa producing areas and country specific, table 5 displays data set for only cocoa specific areas. The reason is to compare the results to find out if there are major differences in the results[54].

Table 4 shows[55] direct association between cocoa output and temperature in the sub-region for almost all the countries except for Guinea. Among all the countries under study, Cote D'Ivoire, Sierra-Leone and Ghana have strong direct linear association than all the remaining countries. Guinea, on the other hand, has an indirect correlation between

[54] The purpose of doing this is in respect of the various arguments in the literature as to whether to use country wide data or crop specific area data.

[55] The data set here relates to the cocoa producing areas and not the data set for the entire country (i.e. the cocoa specific area data is what has been used for the correlation analysis).

temperature and cocoa output. Nigeria, Benin, Togo and Liberia have weak direct correlation as compared to Ghana, Cote D'Ivoire and Sierra-Leone.

In terms of precipitation, there are generally indirect patterns across all the countries under study with different degrees of correlation. Whereas Ghana, Cote D'Ivoire, Togo, Benin and Sierra-Leone have indirect correlation in line with literature, Liberia and Guinea have rather direct correlation between precipitation and cocoa output contrary to evidence in the literature.

Table 4 indicates the significance and size of the correlation analysis for the countries under study. Citing Ghana, both temperature and precipitation are significant in explaining the impact of climate change on cocoa output. However, both temperature and precipitation are weakly positive and negatively correlated to cocoa production respectively.

Using the mean temperature and precipitation data, Cote D'Ivoire has highly positive correlation between temperature and cocoa production, and highly negative correlation between cocoa production and precipitation. In terms of size, the climatic variables fairly explain the nature of correlation in Cote D'Ivoire. In Nigeria, while precipitation is observed to be significant, it is negative and weakly related to cocoa output. Temperature is insignificant and negatively related to cocoa output. It implies that climatic variables weakly explain the relationship between climate variables and cocoa output using the mean data values.

In the case of Togo, Benin, Liberia, Sierra-Leone and Guinea the mean temperature and precipitation data shows there are an insignificant correlation cocoa output the climatic variables. It can therefore be argued that climatic variables weakly explain cocoa production in these countries. Using the country data set it is clear that three major changes have occurred contrary to the result of table 4. These changes occurred in three countries namely Ghana, Benin and Guinea. First, whereas Ghana had both temperature and precipitation to be significant with weak association using dataset from the cocoa producing areas, the country specific average dataset shows only precipitation is significant with strong co-variation between cocoa and precipitation. Second, the dataset for the cocoa producing areas in Benin's case was insignificant but with the country dataset, both temperature and precipitation are significant with weak association between cocoa and the climatic variables. Third, in Guinea's case, both temperature and precipitation displayed strong significant correlation with the use of the country specific dataset. Unlike the use of the other data set, both variables were insignificant and weakly co-varied.

Table 4: Correlation Analysis of Cocoa Output, Temperature and Precipitation

Variable	Cocoa areas Mean Temp	Cocoa areas Mean Precip	Country Average Temp	Country Average Precip	Country
Cocoa Output	0.317* (0.043)	-0.327* (0.037)	0.253 (0.110)	-0.585** (0.000)	Ghana
Cocoa Output	0.545** (0.000)	-0.568** (0.000)	0.328* (0.036)	-0.658** (0.000)	Cote D'Ivoire
Cocoa Output	-0.048 (0.767)	0.339* (0.030)	0.234 (0.140)	-0.593** (0.000)	Nigeria
Cocoa Output	0.183 (0.260)	-0.294 (0.066)	0.197 (0.217)	-0.233 (0.142)	Togo
Cocoa Output	0.074 (0.644)	-0.090 (0.578)	0.346* (0.027)	-0.312* (0.047)	Benin
Cocoa Output	-0.045 (0.778)	0.038 (0.814)	-0.274 (0.083)	-0.280 (0.077)	Liberia
Cocoa Output	0.114 (0.477)	-0.033 (0.809)	-0.040 (0.804)	-0.038 (0.815)	Sierra-Leone
Cocoa Output	-0.041 (0.799)	0.150 (0.350)	0.446** (0.004)	-0.512** (0.001)	Guinea

Correlation is significant at the 0.05 level (2-tailed).** Correlation is significant at the 0.01 level (2-tailed).

Source: Author's estimation using data from FAO Statistics, 2011.

Table 5 depicts the second correlation analysis undertaken using maximum and minimum temperature and precipitation as against cocoa output. The reason for using these values is to ascertain how the impact of climate change in any direction would have on cocoa output in the producing countries. 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. Whereas there is a negative significant correlation between cocoa output and maximum precipitation, minimum precipitation is significant and 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. Maximum precipitation and minimum temperature are significant in Togo and Benin's cases. These variables have the right signs, but weakly co-vary with cocoa output. Maximum temperature and minimum precipitation, on the other hand, have the right signs (except for minimum precipitation for Benin), insignificant and weakly correlate with cocoa output. In Liberia, while maximum precipitation and minimum temperature are significant, maximum temperature and minimum precipitation are insignificant and weakly correlate with cocoa output for all the variables. Except for minimum temperature, the signs are all incorrect for the remaining variables. Maximum temperature and minimum temperature are highly significant and fairly correlate with cocoa output in the case of Sierra-

Leone. Minimum and maximum precipitation, on the other hand, is insignificant, have wrong signs and weakly correlate with cocoa output in Sierra-Leone.

Table 5: Correlation Analysis of Cocoa output, Temperature and Precipitation

Variable	Min Temp	Max Temp	Min Precip	Max Precip	Country
Cocoa Output	0.152 (0.343)	0.179 (0.263)	0.564(**) (0.000)	-0.584(**) (0.000)	Ghana
Cocoa Output	0.177 (0.269)	0.449(**) (0.003)	0.276 (.081)	-0.612(**) (0.000)	Cote D'Ivoire
Cocoa Output	-0.185 (0.248)	0.606(**) (0.000)	0.195 (0.222)	-0.676(**) (0.000)	Nigeria
Cocoa Output	0.317(*) (0.043)	0.070 (0.663)	-0.107 (0.504)	(-0.308) (0.050)	Togo
Cocoa Output	0.415(**) (0.007)	0.151 (0.346)	0.195 (0.223)	-0.366(*) (0.019)	Benin
Cocoa Output	0.211 (0.185)	-0.261 (0.099	0.249 (0.116)	0.045 (0.780)	Liberia
Cocoa Output	0.535(**) (0.000)	0.325(*) (0.038)	.(a) .	-0.055 (0.734)	Sierra-Leone
Cocoa Output	.025 (0.878)	-.146 (0.361)	.(a)	-.524(**) (0.001)	Guinea

**** Correlation is significant at the 0.05 level (2-tailed).** Correlation is significant at the 0.01 level (2-tailed), (a) Cannot be computed because at least one of the variables is constant.***

Source: Author's estimation using data from FAO Statistics, 2011.

Finally, in Guinea, apart from maximum precipitation that is highly significant and fairly correlates with cocoa output, all the other variables are insignificant, and weakly co-vary with cocoa output. In terms of signs, maximum precipitation and minimum temperature have the right signs, but the rest do not have.

5.2. Mean dataset estimation results

The empirical results of the mean climatic dataset along side with labour and capital inputs are reported in table 6. Starting with labour and capital it is clear from the first row that labour to cocoa production is positive in terms of sign and is statistically significant. The significance of the coefficient means that cocoa production largely depends on labour input in West Africa. The estimated regression coefficient value of labour, Ln L, suggests that a 1.0 percent change of labour in the sub-region will increase cocoa output by 0.18 percent per year, holding all other factors constant.

Capital from the second row has a positive sign, but insignificant at the 5 percent level. The non-significance of the estimated regression coefficient implies cocoa production does not momentously depend on capital (Fertilizer) input in the sub-region. With respect to the coefficient of Temperature, it is negative and insignificant. The non-significance of temperature using the mean climatic dataset proposes that temperature is still within the range (variation should not exceed 8ºC per day) that does not considerably affect cocoa production in the sub-region. The sign of the regression coefficient value of -0.30 suggests temperature has a reducing effect on cocoa production, particularly when it is above the stipulated range[56].

The regression coefficient of precipitation is positive and very significant. Its positive coefficient value of 0.77 suggests that cocoa production strongly depends on precipitation in the sub-region. Thus, a 1.0 percent change increase in precipitation in West Africa will

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[56] From the agronomic literature temperature variation for cocoa must not exceed 8^0C per day. The required temperature is 26^0C and daily variation should not exceed or come below 8^0C per day.

increase cocoa production by 0.77 percent per year, holding all other factors in the model at their historical 2009 values.

While precipitation and labour have positive coefficients in the regression, their interaction with cocoa production assumes negative but statistically significant results. This means that the interactive effect of precipitation and labour is significant in cocoa production but that one of the variables reduces the effectiveness of the other. The uni-directional causation is that high precipitation reduces labour input to cocoa production. Hence, the regression coefficient value of -0.23 suggests that a unit increase in precipitation over the required quantity will affect labour input such that the total effect will reduce cocoa output by 0.23 percent per annum in the sub-region.

The coefficients of capital and temperature are positive and negative respectively, but their combined interaction to cocoa production assumes a negative sign. This suggests that high surges or level of temperature reduces the effectiveness of fertilizer input, thereby negatively affecting cocoa production in the sub-region. Their combined effect, however, is insignificant in influencing cocoa production in West Africa when the mean values are used.

The seventh row is a three year lag of temperature with a negative coefficient of -0.86 and significant p-value of 0.040. The indication is that a-three year lags of temperature still affect the output of cocoa in West Africa. This implies that a 1.0 percent change in the previous three years, temperature above the temperature thresh-hold (requirement for cocoa production) will result in a decrease of cocoa output by a margin of 0.86 percent in current year.

Row eight reports a-one year lag of precipitation with a positive coefficient value of 0.93. This value indicates that a-one year lag (t_{-1}) input of precipitation substantially impacts on cocoa production in time t. Therefore, a 1.0 percent change in previous year’s precipitation will substantially improve cocoa output by 0.93 percent across Sub-region in the present year.

The conclusion drawn from the first empirical results on table 6 suggests that given the minimum climatic values, the effect of temperature is not felt in cocoa production in the West African sub-region. However, even with the mean values the impact of precipitation is already visible. It is also important to acknowledge the lag effects of both temperature and precipitation on cocoa production.

Table 6: Results of Mean Dataset Estimation

Fixed Effect Estimation Results		**Random Effect Estimation Results**	
Variables	**Coefficient /(Prob)**	**Variables**	**Coefficient /(Prob)**
Ln L (Labour)	0.180773 (0.000)	Ln L (Labour)	0.07522 (0.000)
Ln K (Capital)	0.5802552 (0.143)	Ln K (Capital)	0.82427 (0.003)
Ln Temp(Temperature)	-0.3019058 (0.773)	Ln Temp(Temperature)	-1.33221 (0.000)
Ln Precip (Precipitation)	0.772345 (0.011)	Ln Precip (Precipitation)	2.006458 (0.227)
Ln LLn P (Labour Precipitation interaction)	-0.2310729 (0.019)	Ln L Ln P(Labour Precipitation interaction)	-.4292913 (0.219)
Ln K Ln T(Capital Temperature interaction)	-0.389708 (0.153)	Ln K Ln T(Capital Temperature interaction)	-0.576147 (0.004)
Ln T(-3) :(three year lag of Temperature)	-0.861819 (0.040)	Ln T(-3) :(three year lag of Temperature	-0.004671 (0.752)
Ln P (-1) :(one year lag of Precipitation).	-0.1436186 (0.002)	Ln P (-1) :(one year lag of Precipitation).	.8680576 (0.000)
No of obs: Number of Groups: Within R^2: Between R^2: Over all R^2: Prob>F	**328** **8** **0.4907** **0.5125** **0.6073** **0.0000**	No of obs: Number of Groups: Within R^2: Between R^2: Over all R^2: Prob>F	**328** **8** **0.5400** **0.7426** **0.6055**

Note: All Variables are significant at the 5 percent level.

Source: Author's Estimation (2011)

5.3. Estimation results of the maximum climatic dataset

Table 7 presents the estimation results the maximum climatic dataset[57]. It is important to recall that the estimation was done alongside leading production variables like capital and labour. Beginning with labour, the first row reports that Labour substantially contributes to cocoa output in West Africa. The positive estimated regression coefficient value of labour suggests that a 1.0 percent change in labour will increase cocoa output by 0.50 percent in West Africa.

The second row table 7 displays the results of Capital with a positive coefficient of 0.13 suggesting that fertilizer is one of the key inputs to cocoa production in West Africa. This result is in contrast to the one acquired using the mean dataset. The intuition is that in extreme temperature events fertilizer input becomes more relevant in the production process of cocoa. The regression results indicate that a 1.0 percent change in fertilizer applied in the cocoa sector in West Africa will increase cocoa output by 0.13 percent per annum.

On the third row, temperature has a negative regression coefficient of -0.57 and statistically significant, suggesting that in extreme events temperature becomes harmful to cocoa production[58]. The result proposes that a 1.0 percent change in temperature in West Africa, above the cocoa production thresh-hold, will decrease cocoa output by 0.57 percent per annum, holding all other factors constant. The implication is that temperature surges strongly affect cocoa production in West Africa.

The Fourth row indicates the significance of precipitation with a regression coefficient of 0.52. Statistically, the positive sign suggests that it directly impacts on cocoa production in West Africa. The coefficient of 0.52 indicates that a 1.0 percent change rise in precipitation supports cocoa production by 0.52 percent per year, with all other things being equal.

The result of the fifth row has to do with the interaction of labour and precipitation. With the maximum dataset, the regression coefficient of the interaction among the two variables is negative as opposed to their respective coefficients. One possible reason is that much of one of them has negative impact on the other thereby affecting cocoa production. The possible agronomic reason is that an extreme increase in precipitation may cause flood or simply would

[57] This data set represents extreme events recorded over the period understudy.
[58] This is where daily variation of temperature exceeds the 8^0C (Celsius).

reduce labour activity, which will in turn negatively impact on cocoa output. In such a situation, the combined effect which is statistically significant in the model suggests there would be a reduction of 0.20 percent of cocoa output during such season. In other words, a 1.0 percent change or reduction in precipitation above the required proportion for cocoa production will reduce cocoa output by 0.20 percent via cocoa labour force.

Result of the sixth row corresponds to the interaction of capital (fertilizer) and temperature with a negative coefficient of -0.46. It suggests that extreme temperature does not combine well with fertilizer application[59]. The implication is that fertilizer application during high periods of temperature would negatively impact on cocoa output. A decline of 0.46 percent of cocoa output would be as a result of a 1.0 percent change of fertilizer applied on cocoa during high temperature (dry) season. In this case, the result could be adjudged as unproductive application of fertilizer.

Row seven represents a-three year lag of temperature with a negative coefficient of -0.69. It is statistically significant, suggesting that temperature effect on cocoa output lingers up to the third year. Thus, a 1.0 percent increase in a three year lag of temperature over the stipulated thresh-hold will still affect cocoa production in time t to the tune of 0.69 percent, all other things being held constant in the model. Finally, the last row covers one year lag of precipitation with a positive coefficient value of 0.93. It is statistically significant, indicating that a previous year's precipitation substantially impacts on cocoa output at the present (time t) period. The coefficient of the result suggests that a 1.0 percent change in a previous year's precipitation above the required quantity will affect cocoa output in current period by a margin of 0.93 percent.

The conclusion from the second empirical analysis is that the extreme effects of climate change are already having impact on cocoa production. This is deduced from the fact that with the maximum dataset (representing extreme events recorded over the years), both temperature and precipitation significantly impact on cocoa output as opposed to only precipitation when the mean dataset was estimated. This can be gleaned from the increase in the size of the coefficient of temperature and a reduction in that of the precipitation. Since the scientific

[59] This is has an agronomic basis for such results. Statistically, the interaction is negative implying together the two variables have reducing effect on cocoa output but the agronomic information is that the excesses of one affect the interaction thereby reducing cocoa output.

reports projects temperature to increase in the nearest future and precipitation to reduce, then it is clear that climate effects are very sure to affect cocoa production in the region. The lag effects are also discernible in table 7 where a three year lag of temperature and one year lag of precipitation considerably affects cocoa production. It is worth noting the interactive effects of capital and temperature on one hand, and precipitation and labour on the other hand.

Table 7: Results of Maximum Dataset Estimation

Fixed Effect Estimation Results		Random Effect Estimation Results	
Variables	**Coefficient / (Prob)**	**Variables**	**Coefficient / (Prob)**
Ln L (Labour)	0.477646 (0.000)	Ln L (Labour)	0.009531 (0.000)
Ln K (Capital)	0.129619 (0.010)	Ln K (Capital)	0.950302 (0.003)
Ln Temp(Temperature)	-0.571764 (0.022)	Ln Temp (Temperature)	-0.199876 (0.000)
Ln Precip (Precipitation)	0.521493 (0.033)	Ln Precip (Precipitation)	0.091319 (0.137)
LnL Ln P(Labour Precipitation interaction)	-0.201018 (0.044)	Ln L Ln P(Labour Precipitation interaction)	-0.565538 (0.066)
Ln K Ln T(Capital Temperature interaction)	-0.464699 (0.011)	Ln K Ln T(Capital Temperature interaction)	-0.654773 (0.142)
Ln T(-3) :(three year lag of Temperature)	-0.685851 (0.011)	Ln T(-3) :(three year lag of Temperature)	0.133989 (0.003)
Ln P (-1) :(one year lag of Precipitation).	0.932871 (0.000)	Ln P (-1) :(one year lag of Precipitation).	0.446205 (0.000)
No of obsv: Number of Groups: Within R^2: Between R^2: Over all R^2: Prob. Chi:	328 8 0.4844 0.5692 0.6628 0.0000	No of obsv: Number of Groups: Within R^2: Between R^2: Over all R^2: Prob. Chi	328 8 0.41158 0.6735 0.6243bb 0.0000

Note: All Variables are significant at the 5 percent level.

Source: Author's Estimation (2011)

5.4. Simulation results

Figure 14, displays the in-sample simulation of cocoa output from the panel regression model, which shows that the model performs very well. In other words, the estimated model has approximated the real-historical values. Econometric theory suggests that the closer the forecasts are to the real values, the better the forecasting power of the Model. The model is, therefore, adjudged as having strong predictive power for forecasting purposes.

Satisfied with the strength of the model, out sample simulation was under taken, the results of which are displayed in table 8 and 9 Although both tables offer the same information, table 8 has been specifically carved out of table 9 to cover the period 2005-2015 for purposes of clarity of exposition. The continuation of table 8 is in appendix B.

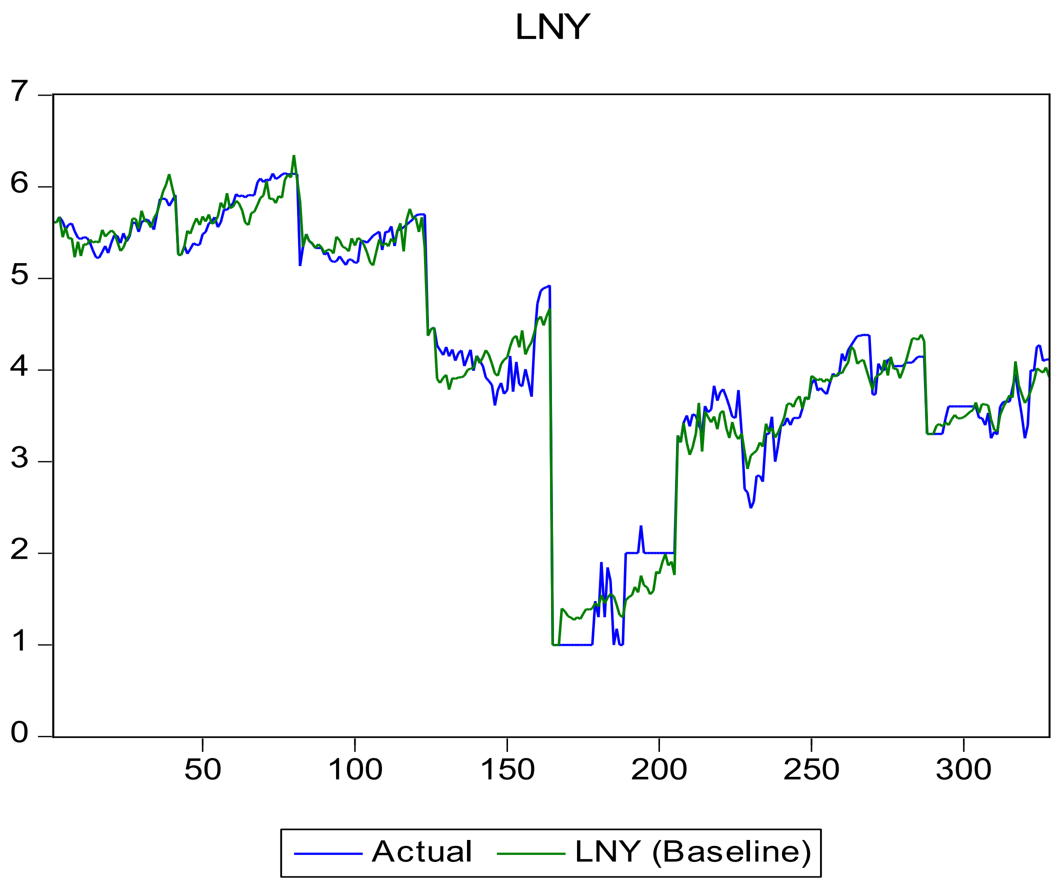

Figure 14: In-sample simulation of Cocoa Output from 1969-2009

Source: In-sample simulation results, (2011).

Table 8: Simulation Results of Temperature and Precipitation effects on Cocoa output

							Precip											
			2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
			2.79588	2.09691	1.39794	0.69897	0	-0.69897	-1.39794	-2.09691	-2.79588	-3.49485	-4.19382	-4.89279	-5.59176	-6.29073	-6.9897	-7.68867
	2005	1.47112	10.50873	9.54974	8.590753	7.631766	**6.672779**	5.713793	4.754806	3.795819	2.836832	1.877845	0.918858	-0.04013	-0.99912	-1.9581	-2.91709	-3.87608
	2006	1.47334	10.19858	9.23959	8.280604	7.321617	**6.36263**	5.403643	4.444656	3.485669	2.526683	1.567696	0.608709	-0.35028	-1.30926	-2.26825	-3.22724	-4.18623
	2007	1.47556	9.888428	8.929441	7.970454	7.011467	**6.05248**	5.093494	4.134507	3.17552	2.216533	1.257546	0.298559	-0.66043	-1.61941	-2.5784	-3.53739	-4.49637
	2008	1.47778	9.578278	8.619291	7.660305	6.701318	**5.742331**	4.783344	3.824357	2.86537	1.906383	0.947397	-0.01159	-0.97058	-1.92956	-2.88855	-3.84754	-4.80652
Temp	2009	**1.487138**	**8.270848**	**7.311861**	**6.352874**	**5.393887**	**4.4349**	**3.475913**	**2.516927**	**1.55794**	**0.598953**	**-0.36003**	**-1.31902**	**-2.27801**	**-3.23699**	**-4.19598**	**-5.15497**	**-6.11395**
	2010	1.48222	8.957979	7.998992	7.040005	6.081019	**5.122032**	4.163045	3.204058	2.245071	1.286084	0.327098	-0.63189	-1.59088	-2.54986	-3.50885	-4.46784	-5.42682
	2011	1.48444	8.64783	7.688843	6.729856	5.770869	**4.811882**	3.852895	2.893909	1.934922	0.975935	0.016948	-0.94204	-1.90103	-2.86001	-3.819	-4.77799	-5.73697
	2012	1.48666	8.33768	7.378693	6.419706	5.46072	**4.501733**	3.542746	2.583759	1.624772	0.665785	-0.2932	-1.25219	-2.21118	-3.17016	-4.12915	-5.08814	-6.04712
	2013	1.48888	8.02753	7.068544	6.109557	5.15057	**4.191583**	3.232596	2.273609	1.314623	0.355636	-0.60335	-1.56234	-2.52132	-3.48031	-4.4393	-5.39829	-6.35727
	2014	1.4911	7.717381	6.758394	5.799407	4.84042	**3.881434**	2.922447	1.96346	1.004473	0.045486	-0.9135	-1.87249	-2.83147	-3.79046	-4.74945	-5.70843	-6.66742
	2015	1.49332	7.407231	6.448245	5.489258	4.530271	**3.571284**	2.612297	1.65331	0.694324	-0.26466	-1.22365	-2.18264	-3.14162	-4.10061	-5.0596	-6.01858	-6.97757
	2016	1.49554	7.097082	6.138095	5.179108	4.220121	**3.261135**	2.302148	1.343161	0.384174	-0.57481	-1.5338	-2.49279	-3.45177	-4.41076	-5.36975	-6.32873	-7.28772
	2017	1.49776	6.786932	5.827945	4.868959	3.909972	**2.950985**	1.991998	1.033011	0.074024	-0.88496	-1.84395	-2.80294	-3.76192	-4.72091	-5.6799	-6.63888	-7.59787
	2018	1.49998	6.476783	5.517796	4.558809	3.599822	**2.640835**	1.681849	0.722862	-0.23613	-1.19511	-2.1541	-3.11309	-4.07207	-5.03106	-5.99005	-6.94903	-7.90802
	2019	1.5022	6.166633	5.207646	4.24866	3.289673	**2.330686**	1.371699	0.412712	-0.54627	-1.50526	-2.46425	-3.42324	-4.38222	-5.34121	-6.3002	-7.25918	-8.21817
	2020	1.50442	5.856484	4.897497	3.93851	2.979523	**2.020536**	1.06155	0.102563	-0.85642	-1.81541	-2.7744	-3.73338	-4.69237	-5.65136	-6.61035	-7.56933	-8.52832
	2021	1.50664	5.546334	4.587347	3.62836	2.669374	**1.710387**	0.7514	-0.20759	-1.16657	-2.12556	-3.08455	-4.04353	-5.00252	-5.96151	-6.92049	-7.87948	-8.83847
	2022	1.50886	5.236185	4.277198	3.318211	2.359224	**1.400237**	0.44125	-0.51774	-1.47672	-2.43571	-3.3947	-4.35368	-5.31267	-6.27166	-7.23064	-8.18963	-9.14862
	2023	1.51108	4.926035	3.967048	3.008061	2.049075	**1.090088**	0.131101	-0.82789	-1.78687	-2.74586	-3.70485	-4.66383	-5.62282	-6.58181	-7.54079	-8.49978	-9.45877
	2024	1.5133	4.615886	3.656899	2.697912	1.738925	**0.779938**	-0.17905	-1.13804	-2.09702	-3.05601	-4.015	-4.97398	-5.93297	-6.89196	-7.85094	-8.80993	-9.76892
	2025	1.51552	4.305736	3.346749	2.387762	1.428775	**0.469789**	-0.4892	-1.44819	-2.40717	-3.36616	-4.32515	-5.28413	-6.24312	-7.20211	-8.16109	-9.12008	-10.0791
	2026	1.51774	3.995586	3.0366	2.077613	1.118626	**0.159639**	-0.79935	-1.75833	-2.71732	-3.67631	-4.6353	-5.59428	-6.55327	-7.51226	-8.47124	-9.43023	-10.3892
	2027	1.51996	3.685437	2.72645	1.767463	0.808476	**-0.15051**	-1.1095	-2.06848	-3.02747	-3.98646	-4.94544	-5.90443	-6.86342	-7.82241	-8.78139	-9.74038	-10.6994
	2028	1.52218	3.375287	2.416301	1.457314	0.498327	**-0.46066**	-1.41965	-2.37863	-3.33762	-4.29661	-5.25559	-6.21458	-7.17357	-8.13255	-9.09154	-10.0505	-11.0095
	2029	1.5244	3.065138	2.106151	1.147164	0.188177	**-0.77081**	-1.7298	-2.68878	-3.64777	-4.60676	-5.56574	-6.52473	-7.48372	-8.4427	-9.40169	-10.3607	-11.3197
	2030	1.52662	2.754988	1.796001	0.837015	-0.12197	**-1.08096**	-2.03995	-2.99893	-3.95792	-4.91691	-5.87589	-6.83488	-7.79387	-8.75285	-9.71184	-10.6708	-11.6298
	2031	1.52884	2.444839	1.485852	0.526865	-0.43212	**-1.39111**	-2.3501	-3.30908	-4.26807	-5.22706	-6.18604	-7.14503	-8.10402	-9.063	-10.022	-10.981	-11.94
	2032	1.53106	2.134689	1.175702	0.216716	-0.74227	**-1.70126**	-2.66024	-3.61923	-4.57822	-5.53721	-6.49619	-7.45518	-8.41417	-9.37315	-10.3321	-11.2911	-12.2501
	2033	1.53328	1.82454	0.865553	-0.09343	-1.05242	**-2.01141**	-2.97039	-3.92938	-4.88837	-5.84736	-6.80634	-7.76533	-8.72432	-9.6833	-10.6423	-11.6013	-12.5603
	2034	1.5355	1.51439	0.555403	-0.40358	-1.36257	**-2.32156**	-3.28054	-4.23953	-5.19852	-6.1575	-7.11649	-8.07548	-9.03447	-9.99345	-10.9524	-11.9114	-12.8704
	2035	1.53772	1.204241	0.245254	-0.71373	-1.67272	**-2.63171**	-3.59069	-4.54968	-5.50867	-6.46765	-7.42664	-8.38563	-9.34461	-10.3036	-11.2626	-12.2216	-13.1806
	2036	1.53994	0.894091	-0.0649	-1.02388	-1.98287	**-2.94186**	-3.90084	-4.85983	-5.81882	-6.7778	-7.73679	-8.69578	-9.65476	-10.6138	-11.5727	-12.5317	-13.4907
	2037	1.54216	0.583942	-0.37505	-1.33403	-2.29302	**-3.25201**	-4.21099	-5.16998	-6.12897	-7.08795	-8.04694	-9.00593	-9.96491	-10.9239	-11.8829	-12.8419	-13.8009
	2038	1.54438	0.273792	-0.68519	-1.64418	-2.60317	**-3.56216**	-4.52114	-5.48013	-6.43912	-7.3981	-8.35709	-9.31608	-10.2751	-11.2341	-12.193	-13.152	-14.111
	2039	1.5466	-0.03636	-0.99534	-1.95433	-2.91332	**-3.8723**	-4.83129	-5.79028	-6.74927	-7.70825	-8.66724	-9.62623	-10.5852	-11.5442	-12.5032	-13.4622	-14.4212
	2040	1.54882	-0.34651	-1.30549	-2.26448	-3.22347	**-4.18245**	-5.14144	-6.10043	-7.05941	-8.0184	-8.97739	-9.93638	-10.8954	-11.8543	-12.8133	-13.7723	-14.7313
	2041	1.55104	-0.65666	-1.61564	-2.57463	-3.53362	**-4.4926**	-5.45159	-6.41058	-7.36956	-8.32855	-9.28754	-10.2465	-11.2055	-12.1645	-13.1235	-14.0825	-15.0415
	2042	1.55326	-0.96681	-1.92579	-2.88478	-3.84377	**-4.80275**	-5.76174	-6.72073	-7.67971	-8.6387	-9.59769	-10.5567	-11.5157	-12.4746	-13.4336	-14.3926	-15.3516
	2043	1.55548	-1.27696	-2.23594	-3.19493	-4.15392	**-5.1129**	-6.07189	-7.03088	-7.98986	-8.94885	-9.90784	-10.8668	-11.8258	-12.7848	-13.7438	-14.7028	-15.6618
	2044	1.5577	-1.58711	-2.54609	-3.50508	-4.46407	**-5.42305**	-6.38204	-7.34103	-8.30001	-9.259	-10.218	-11.177	-12.136	-13.0949	-14.0539	-15.0129	-15.9719
	2045	1.55992	-1.89725	-2.85624	-3.81523	-4.77422	**-5.7332**	-6.69219	-7.65118	-8.61016	-9.56915	-10.5281	-11.4871	-12.4461	-13.4051	-14.3641	-15.3231	-16.2821
	2046	1.56214	-2.2074	-3.16639	-4.12538	-5.08436	**-6.04335**	-7.00234	-7.96133	-8.92031	-9.8793	-10.8383	-11.7973	-12.7563	-13.7152	-14.6742	-15.6332	-16.5922
	2047	1.56436	-2.51755	-3.47654	-4.43553	-5.39451	**-6.3535**	-7.31249	-8.27147	-9.23046	-10.1894	-11.1484	-12.1074	-13.0664	-14.0254	-14.9844	-15.9434	-16.9024
	2048	1.56658	-2.8277	-3.78669	-4.74568	-5.70466	**-6.66365**	-7.62264	-8.58162	-9.54061	-10.4996	-11.4586	-12.4176	-13.3766	-14.3355	-15.2945	-16.2535	-17.2125
	2049	1.5688	-3.13785	-4.09684	-5.05583	-6.01481	**-6.9738**	-7.93279	-8.89177	-9.85076	-10.8097	-11.7687	-12.7277	-13.6867	-14.6457	-15.6047	-16.5637	-17.5227
	2050	1.57102	-3.448	-4.40699	-5.36598	-6.32496	**-7.28395**	-8.24294	-9.20192	-10.1609	-11.1199	-12.0789	-13.0379	-13.9969	-14.9558	-15.9148	-16.8738	-17.8328

Source: Author's Simulation Results (2011).

Table 9: Simulation Results covering 2005-2015

							Precip						
			2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
			2.79588	2.09691	1.39794	0.69897	**0**	-0.69897	-1.39794	-2.09691	-2.79588	-3.49485	-4.19382
	2005	1.47112	10.50873	9.54974	8.590753	7.631766	**6.672779**	5.713793	4.754806	3.795819	2.836832	1.877845	0.918858
	2006	1.47334	10.19858	9.23959	8.280604	7.321617	**6.36263**	5.403643	4.444656	3.485669	2.526683	1.567696	0.608709
	2007	1.47556	9.888428	8.929441	7.970454	7.011467	**6.05248**	5.093494	4.134507	3.17552	2.216533	1.257546	0.298559
	2008	1.47778	9.578278	8.619291	7.660305	6.701318	**5.742331**	4.783344	3.824357	2.86537	1.906383	0.947397	-0.01159
Temp	2009	**1.487138**	**8.270848**	**7.311861**	**6.352874**	**5.393887**	**4.4349**	**3.475913**	**2.516927**	**1.55794**	**0.598953**	**-0.36003**	**-1.31902**
	2010	1.48222	8.957979	7.998992	7.040005	6.081019	**5.122032**	4.163045	3.204058	2.245071	1.286084	0.327098	-0.63189
	2011	1.48444	8.64783	7.688843	6.729856	5.770869	**4.811882**	3.852895	2.893909	1.934922	0.975935	0.016948	-0.94204
	2012	1.48666	8.33768	7.378693	6.419706	5.46072	**4.501733**	3.542746	2.583759	1.624772	0.665785	-0.2932	-1.25219
	2013	1.48888	8.02753	7.068544	6.109557	5.15057	**4.191583**	3.232596	2.273609	1.314623	0.355636	-0.60335	-1.56234
	2014	1.4911	7.717381	6.758394	5.799407	4.84042	**3.881434**	2.922447	1.96346	1.004473	0.045486	-0.9135	-1.87249
	2015	1.49332	7.407231	6.448245	5.489258	4.530271	**3.571284**	2.612297	1.65331	0.694324	-0.26466	-1.22365	-2.18264

Source: Author's Simulation Results (2011).

The first values of the vertical and the horizontal (in thick black) in tables 8 and 9 constitute precipitation and temperature held at their 2009 constant values, holding all other inputs in the production process of cocoa constant. That is to say, the regression (log) values, 0.000 and 1.48724, are 2009 precipitation and temperature values respectively. All other thick (black) figures represent the corresponding cocoa output values at 2009 temperature and precipitation values. Based on the assumptions used, precipitation decreases from 2005 to 2015 in table 9 and beyond as in table 8. Likewise, temperature assume increasing trend from 2005 to 2015 in panel 9 and beyond in panel 8. Cocoa output (in log terms) for 2009 is 4.4349**,** which is at the center of table 9.

Scenario one in table 9 (representing the blue values at the left upper quadrant of the table) shows decreasing temperature and increasing in precipitation. The result of such trend is rising in cocoa output from 4.4349 through 10.50873. This implies that, based on the results of the estimated regression, decreasing temperature and increasing precipitation will lead to a rising cocoa output in the sub-region. However, the rate of change of the increases (that is, from 4.4349 to 6.701318 & to 7.970454 & to 9.23959 & to 10.50873) 2.266418, 1.269136, 1.269136, 1.26914 shows increase, constant and then diminishing increases. This indicates that the combination of increasing precipitation and decreasing temperature trend will lead to increasing cocoa output to a point. But if the trend continues, beyond the required thresh-hold, cocoa output will decline. The implication here is that, a combination of temperature and precipitation in their rightful proportions are ideal for cocoa production.

Scenario two constitutes constant temperature and falling precipitation along the thick black values from 2009-2015. The result shows a declining cocoa output throughout the simulation period. This result implies that, if temperature remains constant and precipitation falls, cocoa output will fall as well. This means cocoa output is very sensitive to these two variables.

Scenario three in 5.3b (upper right quadrant with thick yellow figures) composes of declining precipitation and failing temperature. In such case, cocoa output will also fall throughout the period space. In other words, declining temperature and declining precipitation are not helpful for cocoa production in the sub-region.

In instances of constant precipitation with falling temperature, scenario four, as indicated along the vertical thick black values, cocoa output increases throughout the period. This means, if precipitation is held constant at its 2009 values with declining temperature, cocoa output will continue to increase from its log values of 4.43495 to 5.67551. Computing the rate of change along the increasing vertical line connotes very marginal increases of 0.00001 per anum. What this means is that constant precipitation with decreasing temperature will lead to only marginal increases in cocoa output.

Scenario five (indicating the deep green values in the lower left quadrant of table 9) reflects increasing temperature and increasing precipitation which result in increasing cocoa output, but at a diminishing rate. The implication is that, increasing temperature and increasing precipitation will result in rising cocoa output up to a point (within a range) and then will envisage falling trend (beyond the thresh hold). This suggests that a combination of temperature and precipitation is not enough but that their rightful proportions are also equally important.

The last scenario, (scenario six located at the lower right quadrant of table 9 with red values) considers increasing temperature and decreasing precipitation.

Table 10: Summary of simulation results

SCENARIOS	DESCRIPTION	RESULTS	COMMENT
One	-Decreasing Temperature & increasing Precipitation. -Upper left quadrant (Blue thick values).	-Increasing Cocoa Output is realised.	**-**However, the rate of change increases, becomes constant & diminishes.
Two	-Constant Temperature & Decreasing Precipitaion. (**Thick black values**)	-Cocoa output reduces.	-Suggesting that the blend of the variables are important.
Three	- Decreasing Precipitation & Decreasing Temperature. -Upper right quadrant. (Thick yellow values)	-Cocoa Output reduces.	**-** Not helpful for cocoa production.
Four	**-**Contant Precipitation & Increasing Temperature. **-Vertical thick black values**	-Cocoa Output increases throught out the period.	**-**However, rate of change of growth of output is very marginal.
Five	**-I**ncreasing Temperature & Increasing Precipitation. - Lower left quadrant (Deep green values)	-Increases Cocoa Output.	**-** Increse is at a diminishing rate. Rightful proportions of these variables are important.
Six	**-**Increasing Temperature & Declining Precipitation. -Lower right quadrant (Red Values)	-Cocoa Output falls precipitously.	**-**Detrimental to cocoa production in the sub-region.

Source: Author's Summary from Simulation Results (2011).

The result is a falling cocoa output throughout the simulation period. This result signifies that a increasing temperature in the presence of decreasing precipitation is detrimental to cocoa production in West Africa. This key finding suggests that if the scientific projections given come to pass, then, cocoa output like all agricultural output will decline over years.

5.5. Time series results for the selected countries

Three countries, namely Nigeria, Ghana and Cote D'Ivoire were selected for the time series analysis. The choice of these countries to represent the West African cocoa producing countries is on the basis of the fact that they occupy a sizeable portion of the world market of cocoa, together constituting about 67% of world cocoa output. This study submits that this is representative enough to show the effects of climate change in the entire region. The three countries are hereby discussed in turn using both the mean and maximum climatic variables as was done in the panel case.

This section specifically presents and analyses the results of the various tests and estimations undertaken in this study. It contains the unit root test, cointegration tests, Error Correction (ECM) estimation as well as Vector Error Correction estimation (VECM). Also, several diagnostic tests to appraise the models used have all been done and reported in Appendix F. They include among other stability tests, residual normality test and Portmanteau tests for autocorrelations.

5.5.1. Results of the 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. The formal method to testing the stationarity of a series is the unit root test. Due to this, the study tests all the variables for unit roots to verify their stationarity[60]. A difference stationary series is said to be integrated and is denoted as I(d) where d is the order of integration. The order of integration is the number of

[60] A series is said to be (weakly or covariance) stationary if the mean and autocovariances of the series do not depend on time. Any series that is not stationary is said to be nonstationary.

unit roots contained in the series, or the number of differencing operations it takes to make the series stationary. 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 Unit Root results for the mean and maximum climatic values for these countries are reported in tables 11 to 12 below.

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).

Table 11: Results of Unit Root Tests for Nigerian Mean Values

Variable		Augmented Dickey-Fuller Test Statistic	Phillips-Perron (PP) Statistic	Conclusion
LNY	Levels	-1.2310,(0.1532)	-0.576012,(0.5680)	I(1)
	First Diff	-5.8063**,(0.000)	-6.41959**, (0.0000)	
LNL	Levels	-2.6121, (0.3214)	-3.60559, (0.5000)	I(1)
	First Diff	-8.29921**, (0.000)	-4.4093**, (0.0209)	
LNK	Levels	-3.605593, (0.1034)	-1.3243, (0.0342)	I(1)
	First Diff	-7.84549**, (0.000)	-8.81508**, (0.0001)	
LNT	Levels	-0.6937, (0.4945)	-1.2210, (0.2010)	I(1)
	First Diff	-4.6287**, (0.0001)	-3.1496**, (0.0032)	
LNP	Levels	-2.1023, (0.3044)	-1.1586, (0.2302)	I(1)
	First Diff	-3.2345**, (0.0340)	-3.10235**, (0.0036)	
LNTYR3	Levels	-1.0596, (0.7216)	-2.3530, (0.1612)	I(1)
	First Diff	-2.4020**, (0.0219)	-2.5875**, (0.0136)	
LNLLNP	Levels	-1.3241, (0.0614)	-1.06331, (0.405)	I(1)
	First Diff	-3.6938**, (0.0079)	-3.54366**, (0.0117)	
LNKLNT	Levels	-1.9513, (0.8558)	-0.53529, (0.8734)	I(1)
	First Diff	-5.9993**, (0.000)	-14.3908**, (0.000)	
LNPYR1	Levels	-2.6289, (0.2812)	-1.36684, (0.5887)	I(1)
	First Diff	-6.2774**, (0.0018)	-7.14143**, (0.000)	

Note: **represents variables are significant at the 1 percent level and * at 5% level.

Source: Author's Estimation Results (2011).

Table 12: Results of Unit Root Tests for Nigerian Maximum Values

Variable		Augmented Dickey-Fuller Test Statistic	Phillips-Perron (PP) Statistic	Conclusion
LNY	Levels	-1.2310,(0.1532)	-0.576012,(0.5680)	
	First Diff	-5.8063**,(0.000)	-6.41959**, (0.0000)	I(1)
LNL	Levels	-2.6121, (0.3214)	-3.60559, (0.5000)	
	First Diff	-8.29921**, (0.000)	-4.4093**, (0.0209)	I(1)
LNK	Levels	-3.605593, (0.1034)	-1.3243, (0.0342)	
	First Diff	-7.84549**, (0.000)	-8.81508**, (0.0001)	I(1)
LNT	Levels	-1.6055, (0.3044)	-1.1586, (0.3020)	
	First Diff	-3.1023**(0.0036)	-3.10234**(0.0036)	I(1)
LNP	Levels	-0.7984, (0.1000)	-3.60559,(0.5000)	
	First Diff	-5.0344**,(0.0002)	-9.9763**,(0.0000)	I(1)
LNTYR3	Levels	-1.5494,(0.3080)	-1.2210, (0.2060)	
	First Diff	-3.1298**,(0.0032)	-10.363**,(0.0000)	I(1)
LNLLNP	Levels	-0.7973, (0.4231)	-0.5352, (0.8734)	
	First Diff	-2.7737**,(0.0410)	-14.390**(0.0000)	I(1)
LNKLNT	Levels	-0.9184, (0.3648)	-3.6055, (0.1714)	
	First Diff	-13.8169**,(0.000)	-7.7540**,(0.001)	I(1)
LNPYR1	Levels	-2.6289, (0.2004)	-3.60559, (0.9991)	
	First Diff	-5.9054**,(0.000)	-8.0319**,(0.0000)	I(1)

Note: **represents variables are significant at the 1 percent level and * at 5% level.

Source: Author's Estimation Results (2011).

A careful examination of tables 11 through 12[61] show that the results of both ADF and PP, though differ slightly in terms of figures, they all offer the same conclusion (significance levels). The results indicate 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. Due to this, the null hypotheses could not be rejected at levels. The corresponding *p* values give further detail of the significant levels of these variables. This is the case for both the Augmented Dickey-Fuller (1979) and the Phillips-Perron (1998) class of tests. The implication is that there is unit root in the variables and therefore nonstationary at levels. However, as can be gleaned from the tables, the results of the first difference were all stationary and integrated of the same order one (I(1)). Though the individual series are non-stationary in levels, there could still be a cointegration relationship between them. As such, cointegration was necessary to determine the long-run relationship among the dependent variable and the regressors.

5.5.2. Results of the 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. Therefore, the purpose of the study in this regard was to undertake cointegration test to determine whether the group of the non-stationary series (variables) for the study are cointegrated or not. Because the study envisaged the use of two methods of error correction via the Engle *et al* (1987) and the Vector Error Correction approach by Johansen. Suffice it to say that two forms of cointegration tests were embarked upon.

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

[61] *Tables 13 to 16 representing Ghana and Cote D'Ivoire are reported in appendix C.*

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 17: 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)

Note: All variables were significant at the 1 percent level. Maximum lag selected by SIC is 9.

Source: Author's Estimations Results (2011).

With an inclusion of the lag term of the ECM (-1), the model was run and the values of the Akaike and Schwarz information criteria recorded. The least significant values were removed till a point where a further removal did not reduce the information criteria. The results are presented in table 18 below.

Given the lag length as selected by Schwarz Information Criteria to be 9 lags, the results indicate that there is cointegration among all the variables for all the countries under study. This means that the variables have long run relationships. Cointegration implies that the nonstationary variables are driven by the same persistent stochastic shocks, which are attributable to one or several variables present in the model.

On the other hand, the Johansen's approach of cointegration tests is reported in tables 18, 19, 20, 21, 22, 23) respectively for Nigeria, Ghana and Cote D'Ivoire with (18), (19) and (20) covering the mean values, and (21), (22) (23) representing the maximum climatic values. In this respect, the Johansen-Juselius Maximum likelihood procedure was applied in determining the cointegrating rank of the system and the number of common stochastic trends driving the entire system. The trace statistic and the maximum eigen values as well as the critical values at 1% and 5percent have been reported in the tables (18) and (19) for Nigeria. The remaining results covering Ghana and Cote D'Ivoire are reported in Appendix C.

Whereas the upper block reports the trace statistic, the lower block takes account of the maximum eigen value for comparison. In both cases, these values are compared with the critical values at five percent and one percent for decision on the number of the cointegrating equations.

A careful examination the entire results, though exhibit different figures according to the trace and the maximum eigen values, this confirms that at least there is one cointegrating equation among the variables in all the countries under study. Table 18 denoting the Nigerian Mean values shows that there are at least two cointegrating equations in the series. This fact is true for both the trace and maximum statistics tests values. The remaining tables suggest that there is at most one cointegrating equations in each of the series.

Table 18: Result of the Multivariate Johansen Cointegration Test for Nigeria (Mean Values) based on Trace Statistics & Maximum Eigen Values

Hypothesized No. of CE(s)				Critical Values	
Null	Alternative	Eigen Value	Trace Statistics	5%	1%
$r = 0$	$r = 1$**	0.717443	98.93690	68.52	76.07
$r \leq 1$	$r = 2$*	0.543086	49.64582	47.21	54.46
$r \leq 2$	$r = 3$	0.293493	19.09868	29.68	35.65
$r \leq 3$	$r = 4$	0.129888	5.549233	15.41	20.04
$r \leq 4$	$r = 5$	0.003150	0.123029	3.76	6.65
Notes: -Trace statistics indicates 2 cointegrating equation(s) at the 5% level and 1cointegrating equation at 1% level. *(**) denotes rejection of the hypothesis at 5 %(1%) levels.					
Null	Alternative	Eigen Value	Maximum Eigen Value	Critical Values 5%	1%
$r = 0$	$r = 1$**	0.717443	49.29108	33.46	38.77
$r \leq 1$	$r = 2$*	0.543086	30.54714	27.07	32.24
$r \leq 2$	$r = 3$	0.293493	13.54945	14.07	18.63
$r \leq 3$	$r = 4$	0.003150	0.123029	3.76	6.65
Notes: Maximum Eigen Value test indicates 2 cointegrating equation(s) at the 5% level and 1 cointegrating equation(s) at the 1% level. *(**) denotes rejection of the hypothesis at 5 %(1%) level.					

Source: Author's Estimations Results (2011).

Table 19: Result of the Multivariate Johansen Cointegration Test for Nigeria (Maximum Values) based on Trace Statistics and Maximum Eigen Values.

Hypothesized No. of CE(s)				Critical Values	
Null	Alternative	Eigen Value	Trace Statistics	5%	1%
$r = 0$	$r = 1**$	0.827856	106.5884	68.52	76.07
$r \leq 1$	$r = 2$	0.487780	37.97097	47.21	54.46
$r \leq 2$	$r = 3$	0.170894	11.87992	29.68	35.65
$r \leq 3$	$r = 4$	0.108542	4.571012	15.41	20.04
$r \leq 4$	$r = 5$	0.002305	0.090013	3.76	6.65
Notes: -Trace statistic indicates 1 cointegrating equation(s) at the 5% level and 1cointegrating equation at 1% level. *(**) denotes rejection of the hypothesis at 5 %(1%) levels.					
Null	Alternative	Eigen Value	Max. Eigen Value	Critical Values 5%	Critical Values 1%
$r = 0$	$r = 1**$	0.827856	68.61743	33.46	38.77
$r \leq 1$	$r = 2$	0.487780	26.09105	27.07	32.24
$r \leq 2$	$r = 3$	0.170894	7.308905	20.97	25.52
$r \leq 3$	$r = 4$	0.108542	4.480999	14.07	18.63
$r \leq 4$	$r = 5$	0.002305	0.090013	3.76	6.65
Notes: Maximum Eigen Value test indicates 1 cointegrating equation(s) at the 5% level and 1 cointegrating equation(s) at the 1% level. *(**) denotes rejection of the hypothesis at 5 %(1%) level.					

Source: Author's Estimation Results, 2011.

The combined results, therefore implies that, the null hypothesis of no cointegrating equation can be confidently rejected and in essence proceed to estimate for the vector error correction model (VECM). That is to say, $r \neq 0$ but that $r = 1$. The implication is that there is a long run relationship between or among cocoa (LNY) output and the climatic variables as well as the other lead variables in the production process of cocoa in West Africa. This also implies that one can distinguish a short run structure from a long run structure. VAR models allow for modeling simultaneous equations, that is, systems of equations with dynamic interactions.

5.5.3. Results and Analysis of the Engle-Granger Error Correction Model (ECM)

This subsection reports the results of the Error Correction Estimation of Engle Granger (1987) for the three selected countries. The over-parameterized specification that yielded these parsimonious results is found in tables D1 to D6 in appendix D for pedagogy.

Whereas table 24 reports the results of the mean climatic values, table 25 reports the maximum values of the ECM for Nigeria. An examination of the report in table 24 indicates that the value of the Error Correction Mechanism [ECM (-1)] is negative (as expected), significant and has a high value of 0.67. This suggests that, using the mean values for Nigeria's case, deviations from equilibrium are corrected at about 67% per annum. All the variables in the model are significant implying that they do have significant short term effects on cocoa output except for capital (LNK) which appears to have no significant short term effect on cocoa output.

The third row of the table indicates that a 1.0 percent change in the cocoa labour force of Nigeria will result in a 0.55 percent increase in cocoa output. The significance of the labour value implies that cocoa production in Nigeria is largely influenced by labour input.

Precipitation is reported in the fourth row and significant, suggesting that cocoa output in Nigeria depends on precipitation. The regression coefficient of 0.562 implies that a 1.0 percent change in precipitation will induce cocoa output to increase by 0.56 percent.

Row six indicates the interaction between labour and precipitation as inputs to cocoa production in Nigeria. Unlike the panel case, the regression coefficient is positive and significant indicating that cocoa production fare well with the interaction of labour and precipitation with their combined effect supporting cocoa production in Nigeria.

Table 24: Results of the ECM on Nigeria's Mean Climatic Values

Variable	Coefficient	Std. Error	t-statistic	Prob.
CONSTANT (C)	-0.498670	0.050012	-9.066657	0.0000
D(LNK)	-0.071734	0.320586	-1.675353	0.1054
D(LNL)	0.546340	0.007766	-7.034641	0.0000
D(LNP)	0.561576	0.025906	4.483802	0.0000
D(LNY)	0.628493	0.068864	9.126586	0.0001
D(LNLLNP)	0.383494	0.066212	5.791938	0.0000
D(LNKLNT)	0.417006	0.011029	4.262235	0.0000
D(LNT)	-0.39678	0.059339	-5.073836	0.0002
D(LNK(-1))	-0.223810	0.011029	-2.311624	0.0000
D(LNLLNP(-1))	0.288088	0.051433	5.601217	0.0287
ECM(-1)	-0.671087	0.092234	-7.275957	0.0000
R^2* :** ***Adj R^2* :** ***S.E ***SS resid:*** ***Log likelihood:*** ***DW stat:***	0.828643 0.758831 0.037896 0.038776 79.47520 1.826959	***Mean depnt Var*** ***S.D depnt Var:*** ***Akaike I C:*** ***S.C:*** ***F-statistics:*** ***Prob (F-stat):***	0.007691 0.077168 -3.460267 -2.948401 11.896963 0.000000	

Source: Author's Estimations Results (2011).

The coefficient value suggests that a 1.0 percent change in their combined interaction leads to 0.383 percent increase in cocoa output. Also, a one year interactive effect of precipitation, as recorded on the last row, has a positive impact on cocoa output. This suggests that previous effective and interactive use of labour and precipitation yields significant improvement in cocoa output in Nigeria. Thus, a 1.0 percent change in the previous year's interaction of labour and precipitation in cocoa production will lead to a 0.288 percent increase in present year's cocoa output.

Row seven reflects the interactive effect of temperature and capital in the Nigeria's case. With a significant positive sign, it suggests that the interactive effect of these two variables promotes cocoa production in Nigeria. A 1.0 percent change in their interactive effect will lead to 0.47 percent increases in cocoa output.

The report on row eight indicates that temperature also has significant impact on cocoa output in Nigeria. The negative coefficient sign suggests that a 1.0 percent change in temperature above the required quantity will decrease cocoa out by 0.396 percent in Nigeria. Though capital is not significant, a one year capital input shows a negative impact on cocoa output in Nigeria. The result indicates that a 1.0 percent change in capital over the required quantity in the previous year affects cocoa output in current year by 0.22 percent. This result means that the one year application of fertilizer still impacts on cocoa output in current year with regards to Nigeria's case.

Table 25 indicates the results of the Maximum values for Nigeria. The ECM term suggests that past deviations from equilibrium are restored by 57%. The speed of adjustment in this case is lower than that of table 25. A possible explanation for this could be that as temperature rises with precipitation declining, it takes a longer period for equilibrium to be restored, holding all other factors constant.

Labour input is significant as with the mean values in Nigeria's case. As reported on the second row, the positive regression coefficient of 0.493 suggests that labour input is very monumental in Nigeria's cocoa production. A 1.0 percent change in the cocoa labour force suggests an increase in cocoa output by 0.493 percent, holding all other factors constant.

Table 25: Results of the ECM on Nigeria's Maximum Climatic Values

Variable	Coefficient	Std. Error	t-statistics	Prob.
CONSTANT (C)	-0.380923	0.056094	-6.790694	0.0000
D(LNL)	0.492948	0.073020	6.750886	0.0000
D(LNK)	0.058929	0.012645	-4.660389	0.0001
D(LNKLNT)	0.257980	0.008111	3.180441	0.0034
D(LNLLNP(-1))	0.160156	0.049107	3.261338	0.0028
D(LNLLNP)	0.219128	0.049805	4.399696	0.0001
D(LNP)	0.059080	0.012090	0.488677	0.6286
D(LNT)	-0.846517	0.268592	3.151688	0.0037
ECM(-1)	-0.568292	0.100796	-5.638018	0.0000
R^2 : ***Adj R^2 :*** ***S.E*** ***SS resid:*** ***Log likelihood:*** ***DW stat:***	0.695185 0.613902 0.047950 0.068975 68.24408 1.720557	***Mean depnt Var*** ***S.D depnt Var:*** ***Akaike I C:*** ***S.C:*** ***F-statistics:*** ***Prob (F-stat):***	0.007691 0.077168 -3.038158 -2.654259 8.552564 0.000005	

Source: Author's Estimations (2011).

The third row indicates capital input with low coefficient value of 0.0589. Unlike the panel case, capital becomes relevant as temperature increases and precipitation reduces. The positive regression coefficient suggests that a 1.0 percent change in capital will increase cocoa output by 0.0589 percent in Nigeria. Row four indicates the interactive effect of capital and temperature as having positive impact on cocoa output in Nigeria. The coefficient indicates that a 1.0 percent change in the interaction of fertilizer and temperature will lead to a 0.258 percent increase in cocoa output in Nigeria.

A year lag value and current value of labour and precipitation interaction as indicated in row five and six respectively do have substantial effects on cocoa output in Nigeria. A 1.0 percent change in these interactions will respectively lead to 0.160 and 0.219 in cocoa output in Nigeria. With the maximum dataset for Nigeria's case, precipitation has a positive but insignificant value suggesting that cocoa output does not respond to high levels of precipitation. What this implies is that excessive rainfall does not augur well for cocoa production in Nigeria. This means right proportions of precipitation support cocoa output.

Temperature is negative and significant with a high coefficient value, suggesting that cocoa output largely depends on temperature. In this case, a 1.0 percent change in temperature beyond the required quantity, given the maximum values will lead to a 0.85 percent decrease in cocoa output in Nigeria. Table 26 reports the ECM results for Ghana using the mean values. In this table, the ECM term suggests that deviations from equilibrium are restored by 43% annually in Ghana's case. 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's situation.

In terms of the variables in the model, row two reports that temperature is negative and not significant with the mean value estimation for Ghana. This implies that in Ghana's case, although temperature could have negative impact on cocoa output, it has not reached (gone beyond) the tipping point to offset cocoa growth thereby impacting on the output. The interaction of labour and precipitation is reported on the third row with a significant regression coefficient of 0.746. The significant coefficient suggests that the interactive effects of precipitation and labour substantially contribute to cocoa output in Ghana. In this case, a 1.0 percent change in the combined value will lead to a 0.746 percent increase in cocoa output in Ghana. On the other hand, a-one year lag of the same interaction do not impact on cocoa output, as reported in row twelve. In Ghana's case, the interaction of capital and temperature is negative and insignificant with a regression coefficient of 0.138. The non-significance of this value suggests that the interactive effect of capital (fertilizer) and temperature is not majorly felt in cocoa production in Ghana. The negative sign proposes that one of the variables has a reducing effect on the other though their combined effect does not affect cocoa output. Indeed, high temperature may require more fertilizer, but high temperature could also mean a reduction in the effectiveness of fertilizer application.

One year lag of capital, as recorded on row five, is significant and positive. This is suggesting that the previous year's fertilizer input still impacts on cocoa output in the present year in Ghana's case. The regression coefficient suggests that a 1.0 percent change of the preceding year's fertilizer application leads to a 0.381 percent increase in cocoa output in Ghana.

Row six reports a two year lag of temperature, which has the right sign, but inconsequential in cocoa output. This means that, in Ghana's case, two years' temperature do not substantially impact on cocoa output. However, one years' temperature as recorded on row seven is significant, has a positive sign contrary to expectation and with a regression coefficient value of 0.517. This means, whereas two year's temperature do not affect cocoa output, a year's temperature momentously impact in Ghana. The positive coefficient sign suggests that a 1.0 percent change in temperature in the past year increases cocoa output by 0.517 percent in Ghana's case. This result is contrary to what was observed in the panel study in the entire region.

Row eight reports two years precipitation with insignificant coefficient implying that two years precipitation had no effect in Ghana's case. Row ten reports that a year's precipitation for Ghana mean dataset is significant. The regression coefficient of 0.048 implies that a 1.0 percent change in a year's precipitation is positive but marginally increases cocoa output by 0.048 percent in Ghana.

Table 26: Results of the ECM on Ghana's Mean Climatic Values

Variable	Coefficient	Std. Error	t-statistics	Prob.
CONSTANT (C)	-0.112286	0.042384	-2.649236	0.0147
D(LNT)	-0.1890063	1.796305	-1.052195	0.3041
D(LNLLNP)	0.746263	0.306305	2.436339	0.0234
D(LNKLNT)	-0.13788	0.727472	-1.564157	0.1321
D(LNK(-1))	0.381121	0.047462	2.320000	0.0300
D(LNT(-2))	-0.707991	0.690560	-1.025241	0.3164
D(LNT(-1))	0.517678	0.052695	-2.325247	0.0297
D(LNP(-2))	0.031330	0.023768	-1.318180	0.2010
D(LNTYR3(-1))	-0.053404	0.033229	-1.607151	0.1223
D(LNP(-1))	0.048149	0.023860	-1.865025	0.0756
D(LNTYR3(-2))	-0.538520	0.023452	-2.257026	0.0343
D(LNLLNP(-1))	0.236485	0.190079	1.244140	0.2265
ECM(-1)	-0.434610	0.151470	-2.869287	0.0089
R^2 : ***Adj R^2 :*** ***S.E*** ***SS resid:*** ***Log likelihood:*** ***DW stat:***	0.510098 0.176074 0.070481 0.109287 57.25618 1.830103	***Mean depnt Var*** ***S.D depnt Var:*** ***Akaike I C:*** ***S.C:*** ***F-statistics:*** ***Prob (F-stat):***	0.006221 0.077648 -2.171378 -1.481868 1.527130 0.0178630	

Source: Author's Estimations Results (2011).

Table 27 reports the ECM estimation results on Ghana's maximum values. The error mechanism is negative as expected and a coefficient value of -0.712, suggesting that 71% of previous year's disequilibrium is corrected for in the present period. In terms of the variables making up the Ghana's estimation results, the second row shows labour input with a significant p-value and a positive regression coefficient of 0.140. This suggests that labour input which was dilated before, is essential in the production of cocoa in Ghana. In this case, the result presages that 1.0 percent change in labour force increases cocoa output by 0.140 percent.

The third row reports temperature input with a negative sign, significant and a high coefficient value indicating that cocoa output in Ghana substantially depends on temperature. Unlike the mean values which was insignificant in Ghana's case, the maximum values depicts that temperature has a negative relationship with cocoa output. What this explains is that a rise in temperature beyond the expected threshold negatively impacts on cocoa growth thereby affecting its output. A 1.0 percent change in temperature above the expected requirement will lead to a fall of cocoa output by 0.776 percent in Ghana.

Rows four and five respectively report a-one and two years' capital input to cocoa output in Ghana. Both variables are significant and positive suggesting that a two year and a year's capital input to cocoa output significantly still affect current cocoa output in Ghana. This result therefore, implies that per 1.0 percent change of a year and two years fertilizer application still impacts on cocoa output at the present year in Ghana. This is opposite to the Nigeria's case where capital was insignificant in determining cocoa output.

Rows seven and eight respectively report a year and two year's lags of precipitation in Ghana's case. The two variables are significant and with close positive coefficient values. The significance of their regression coefficients suggests that precipitation like temperature does not have instantaneous effect on cocoa output. A 1.0 percent change of previous two years and a year's precipitation increases cocoa output by 0.272 percent and 0.208 percent respectively in Ghana's case.

Table 27: Results of the ECM on Ghana's Maximum Climatic Dataset

Variable	Coefficient	Std. Error	t-statistics	Prob.
CONSTANT (C)	-0.315404	0.079679	-2.980733	0.0071
D(LNL)	0.1400089	0.031780	-3.063053	0.0299
D(LNT)	-0.776000	0.094741	-2.096496	0.0483
D(LNTYR3)	0.6843083	0.159482	2.0840170	0.0496
D(LNK(-1))	0.5444510	0.079627	2.6645580	0.0145
D(LNK(-2)	0.2637480	0.045254	2.317723	0.0306
D(LNP(-1))	0.2081780	0.047447	5.109325	0.0000
D(LNP(-2))	0.2724561	0.037372	5.070154	0.0001
D(LNTYR3(-1))	0.8678210	0.123386	2.996252	0.0069
D(LNTYR3(-2))	0.3249490	0.087948	2.253512	0.0350
D(LNLLNP(-1))	-0.2937562	0.042063	-5.115866	0.0000
D(LNLLNP(-2))	-0.3845890	0.057801	-5.075059	0.0000
D(LNKLNT(-1))	-0.1089484	0.040850	-2.666976	0.0144
D(LNKLNT(-2))	-0.892666	0.383755	-2.326135	0.0301
D(LNPYR1(-2))	0.517662	0.247349	2.092843	0.0487
ECM(-1)	-0.712734	0.119073	-5.985703	0.0000
R^2 : ***Adj R^2 :*** ***S.E*** ***SS resid:*** ***Log likelihood:*** ***DW stat:***	0.821049 0.684705 0.043600 0.039921 76.39090 1.554967	***Mean depnt Var*** ***S.D depnt Var:*** ***Akaike I C:*** ***S.C:*** ***F-statistics:*** ***Prob (F-stat):***	0.006221 0.0776448 -3.125837 -2.393233 6.021893 0.000103	

Source: Author's Estimations Results (2011).

The lag interactive effects of labour and precipitation on one hand and that of capital, and temperature on the other hand are discernible. Rows eleven and twelve display a one year's lag and two years' lag effects of labour and precipitation respectively. The significance of these variables suggests that their combined effect substantially impact on cocoa output in Ghana. A 1.0 percent change of the combined interactive effect of a year as well as two years' will respectively lead to 0.293 percent and 0.384 percent fall in cocoa output. It would be recalled that their individual participation in the system resulted in positive coefficient, but their combined interaction has negative signs indicating that one has a reducing effect on the other. As dilated before in the panel case, excessive precipitation reduces the efficiency of labour input for Ghana's case.

Finally, a year and two years interactive effect of temperature and capital are also reported in rows thirteen and fourteen. They have negative coefficient values and are significant with coefficient values of- 0.109 percent and -0.892 percent respectively for a year's lag and two years lag. By convention, temperature has a negative sign whereas capital has positive sign. Therefore, their combined effect assuming negative sign implies temperature effect is stronger than that of capital. A probable explanation is that fertilizer application becomes ineffective at high temperatures thereby leading to a fall in cocoa output in Ghana's case. In this light, a 1.0 percent change in the combined effect of a year and two years' fertilizer in high temperature periods respectively reduces cocoa output by 0.109 percent and 0.892 percent.

Table 28 reports the results of the mean climatic values for Cote D'Ivoire. A closer examination of the table shows that the error term, unlike the other mean value results for Ghana and Nigeria, is very high and negative as expected. In Cote D'Ivoire's case, the adjustment value implies that about 83% of previous year's disequilibrium is restored at the present year.

Row one reports labour as an input to cocoa production, which is significant and positive in sign. The significance of the regression coefficient suggests that labour is essential in cocoa production in Cote D'Ivoire. The result shows that a 1.0 percent change in labour force will lead to a 0.647 percent increase in cocoa output in Cote D'Ivoire.

In row two, temperature is significant and has negative regression coefficient. Its significance level implies temperature is relevant in cocoa production in Cote D'Ivoire. This result indicates that a 1.0 percent change in temperature above the required threshold will decrease cocoa output by a 0.468 percent per year, holding all other things equal.

A three year lag of temperature in Cote D'Ivoire's case still lingered over to the time t. Row four shows that a-three year rise in temperature over the requirement for cocoa growth reduces cocoa output by 0.329 percent in current year. Present period and the preceding two years capital interaction with temperature has substantial effects on cocoa output in Cote D'Ivoire as can be observed in row five and thirteen respectively. A 1.0 percent change in these variables will result in an increase in cocoa output by 0.036 percent and 0.464 percent respectively for current year and two years' lag.

The sixth row mirrors a-one year lag of the dependent variable (cocoa output). The lag of a dependent variable on the right hand side of the model is tantamount to lagging all the regressors by the same lag length. What this, therefore, implies is that the lag effects of all the inputs to cocoa output are very much essential in determining cocoa production in Cote D'Ivoire's case. A 1.0 percent change in a year lag value of any of the independent variables will correspondingly increase cocoa output by a percentage change in its coefficient value.

Two years lag of labour; capital and temperature have all shown from the table to have various impacts on cocoa output in Cote D'Ivoire in various degrees. Whereas a 1.0 percent changes in two years' lag of temperature above the required quantity negatively affect current cocoa output by 0.778 percent that of capital and labour increases respectively by 0.664 percent and 0.730 percent. On the mean values of Cote D'Ivoire is a-two year interaction of capital and temperature as having positive impact on cocoa output. From the result as on row thirteen, a 1.0 percent change in a two year combined effect of capital and temperature increases cocoa output by 0.464 percent.

Table 28: Results of the ECM on Cote D'Ivoire's Mean Climatic Dataset

Variable	Coefficient	Std. Error	t-statistics	Prob.
CONSTANT (C)	0.029035	0.014752	1.968238	0.0612
D(LNL)	0.647971	0.079064	3.116648	0.0049
D(LNT)	-0.4684863	0.029184	5.649964	0.0000
D(LNTYR3)	-0.3290531	0.079240	-5.695680	0.0000
D(LNKLNT)	0.0367590	0.009685	3.795398	0.0009
D(LNY(-1))	0.4874360	0.022189	2.196675	0.0384
D(LNL(-2))	0.7305449	0.298752	-3.178006	0.0042
D(LNK(-2))	0.6640469	0.056891	-4.232534	0.0003
D(LNT(-2))	-0.7783509	0.434251	-6.093592	0.0000
D(LNP(-1))	0.172687	0.028339	-6.093592	0.0000
D(LNTYR3(-1))	-0.1915682	0.065890	2.907369	0.0079
D(LNTYR3(-2))	-0.7094475	0.094260	-6.483317	0.0000
D(LNKLNT(-2))	0.464068	0.104180	4.233067	0.0003
D(LNPYR1(-1))	0.040287	0.012713	3.168966	0.0043
ECM(-1)	-0.828318	0.173538	-4.773128	0.0001
R^2 :	0.947636	***Mean depnt Var***	-0.005720	
Adj R^2 :	0.915762	***S.D depnt Var:***	0.174465	
S.E	0.050636	***Akaike I C:***	-2.840921	
SS resid:	0.058972	***S.C:***	-2.194505	
Log likelihood:	68.97749	***F-statistics:***	29.73093	
DW stat:	2.142940	***Prob (F-stat):***	0.0000	

Source: Author's Estimations Results (2011).

Table 29 displays the estimation results of the maximum climatic values of Cote D'Ivoire. The error correction mechanism contrary to the mean values has lower speed of adjustment. This result corroborates the Nigeria's case, but in 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 portrays that, given the data set; each country in the sub-region has its level of adjustment towards equilibrium after climatic distortions. In other words, the carrying capacity of each country determines the speed of adjustment when there is a climate shock (hot season or low precipitation) on cocoa production.

In terms of the other variables making up the model, the second row reports capital input as positive and significant suggesting cocoa output in Cote D'Ivoire crucially depends on fertilizer input. As a result, a 1.0 percent change in fertilizer input will increase cocoa output by 0.499 percent. The third row displays temperature as significant and negative. Unlike the Ghana's mean case where temperature was not significant, Cote D'Ivoire has temperature to be significant at both the use of mean and maximum climatic values. The significant negative regression coefficient suggests that a 1.0 percent change in temperature above the required threshold will decrease cocoa output by 0.455 percent. This confirms the earlier results of the panel and the simulation results that temperature needs to be in its right quantity to influence cocoa output.

A-three year lag of temperature as indicated on row four still impacted on cocoa output in Cote D'Ivoire. What this means is that, temperature effects linger up to three years and has negative impact on cocoa output in year t, in Cote D'Ivoire's case. A 1.0 percent change in temperature in the previous three years above the expected amount will lead to a fall in cocoa output in the present year by 0.390 percent.

The lag effect of a two year capital input is also reported on row five and indicates a positive and significant coefficient value. It shows that the lag effects of capital to a three crop like cocoa is very crucial in its growth and therefore its output. In this case, a 1.0 percent change

Table 29: Results of the ECM on Cote D'Ivoire's Maximum Climatic Dataset

Variable	Coefficient	Std. Error	t-statistics	Prob.
CONSTANT (C)	0.022802	0.010605	2.1500055	0.0403
D(LNK)	0.499450	0.015409	3.241349	0.0031
D(LNT)	-0.455075	0.046447	5.376317	0.0000
D(LNTYR3)	-0.390685	0.190587	-5.429936	0.0000
D(LNK(-2))	0.585045	0.075459	-3.308484	0.0026
D(LNT(-2))	-0.806118	0.178452	4.517265	0.0001
D(LNP(-1))	0.107935	0.029985	-3.599642	0.0012
D(LNTYR3(-2))	-0.574692	0.162607	-4.551632	0.0001
D(LNKLNT(-2))	0.484976	0.235680	3.305853	0.0026
ECM(-1)	-0.390203	0.147508	-2.170751	0.0386
R^2 : ***Adj R^2 :*** ***S.E*** ***SS resid:*** ***Log likelihood:*** ***DW stat:***	0.900434 0.868431 0.063283 0.112131 56.76809 2.112940	***Mean depnt Var*** ***S.D depnt Var:*** ***Akaike I C:*** ***S.C:*** ***F-statistics:*** ***Prob (F-stat):***	-0.005720 0.174465 -2.461478 -2.030535 28.13565 0.00000	

Source: Author's Estimations Results (2011).

in the application of fertilizer in the previous two years' season increases cocoa output by 0.585 percent in Cote D'Ivoire.

Row six in table 5.8(f) reports a two year lag of temperature input as significant and with a negative regression coefficient suggesting that lag values of temperature is very relevant in cocoa production when the maximum values are used. The indication is that a 1.0 percent change in temperature above the stipulated threshold[62] will decrease cocoa output by 0.806 percent. Rows seven and nine report the results of one year lag of precipitation and a-two year lag interaction of capital and temperature respectively. Both variables are significant and positive in their respective regression coefficients. The indication is that a 1.0 percent change in either of the variables will lead to 0.107 percent and 484 percent increase in cocoa output respectively for precipitation and the interaction of capital and temperature.

These results of the ECM do not differ much in general from that of the panel study results, however, there are sharp country variations in the outcomes of the climatic impact on cocoa output. As a whole, temperature and precipitation do have substantial effects on cocoa production in West Africa.

5.5.4. Results and Analysis of the Vector Error Correction Estimation (VECM).

This subsection reports the results of the Johansen's Vector Error Correction estimation for the three countries in turn. This approach, like the Engle-Granger's Error Correction Mechanism helps evaluate the short run behavior and the adjustment to the long run model. The results are reported in tables 30, 31, 32, 33, 34, 35) respectively for Nigeria mean values, Nigeria maximum values, Ghana mean values, Ghana maximum values, Cote D'Ivoire mean values and Cote D'Ivoire maximum values.

Table 30 reports the results of Nigeria's mean climatic values whereas table 31 shows the results of the maximum climatic values. In this section, the interpretation centers on individual relationship (impact) on the dependent variable and not on the respective columns. What this proposes is that, attention is given to only column one of the various preceding tables for purposes of focus and succinctness.

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[62] The required temperature is 26^0C. Recall that daily variations should not exceed 8^0C per day.

As regards the results, it is clear from row one that the error correction term is negative and less than one as theory expects, but has very low speed of adjustment. This suggests that only 29% of the previous year's distortions are corrected for in the Nigeria's case when the mean values are used.

The fourth and fifth rows present a one year and two years lag coefficients of labour as input to cocoa production. Consequently, a 1.0 percent change in labour input will increase cocoa output by 0.185 percent and 0.401 percent respectively. Likewise, the sixth and the seventh row reflect a year and two years lag effects of capital on cocoa output. The results show that 1.0 percent change in the year's lag of capital will increase cocoa output by 0.240 percent. The two years capital, however, is not significant implying a two year fertilizer application does not impact on cocoa output. This fact is similar to the mean result under the Engle-Granger ECM approach for Nigeria. In that report, whereas capital was not significant one year capital was significant. In this report, whereas one year capital is significant, the year two lag is insignificant in Nigeria's case.

Further, rows eight and nine report a year and two years' lag effects of temperature on cocoa output for Nigeria. The significance of the results show that a 1.0 percent change in temperature input beyond the requisite threshold will decrease cocoa output by 0.296 percent and 0.279 percent respectively. Rows ten and eleven show the effects of a year and two years precipitation on cocoa output in Nigeria's case. The report indicates that whereas a year's precipitation is significant that of two years is not. Accordingly, a 1.0 percent change in a year's precipitation will lead to 0.408 percent increase in cocoa output.

From table 31, the ECT in row one is negative and with a coefficient value of 0.387, suggesting that in using the maximum climatic values for Nigeria, the speed of adjustment increases. This is opposite to the result obtained in the Engle-Granger ECM approach for Nigeria. This result suggests that the preceding year's disequilibrium is corrected at about 39% annually.

Rows four and five display the results of labour in a year lag and a two year lag with positive significant regression coefficients. The results suggest that 1.0 percent change in labour input in two year's lag and a year lag will increase cocoa output by 0.149 and 0.339 respectively in Nigeria's case.

Table 30: Results of the VECM Estimate on Nigeria's Mean Climatic Dataset

SYSTEM EQUATIONS					
Variable	D(LN Y)	D(LNL)	D(LNK)	D(LNT)	D(LNP)
ECT	**-0.299176** (0.04262) [3.03121]***	**-0.167037** (0.05371) [1.98641]*	**-0.429438** (0.38169) [-1.12509]	**-0.168430** (0.01852) [-2.36953]**	**-0.150630** (0.01267) [1.68995]*
D(LNY(-1))	**0.126153** (0.08780) [3.00897]***	**-0.145463** (0.02367) [1.68874]*	**0.404176** (1.68209) [0.24028]	**-0.062947** (0.08161) [-0.77129]	**-0.042879** (0.05584) [-0.76791]
D(LNY(-2))	**0.538402** (0.07893) [-3.0897]***	**-0.553225** (0.23728) [-0.24528]	**0.291197** (0.06820) [1.76029]*	**0.113660** (0.08161) [-1.69711]*	**-0.042879** (0.05584) [-1.46301]
D(LNL(-1))	**0.18577** (0.01412) [1.93153]*	**0.402575** (0.17803) [-2.26125]**	**1.11672** (0.12650) [-0.09227]	**0.005726** (0.00614) [-0.93289]	**0.003858** (0.00420) [-0.91882]
D(LNL(-2))	**0.40181** (0.01447) [2.01250]*	**0.143857** (0.18235) [0.78890]	**0.064879** (0.12957) [-0.50072]	**0.002172** (0.00629) [-0.34545]	**-0.001515** (0.00432) [-0.35231]
D(LNK(-1))	**0.240226** (0.02422) [-2.71443]**	**0.278134** (0.30536) [-0.91085]	**0.673124** (0.21698) [-3.1023]***	**0.004793** (0.01053) [0.45528]	**0.003396** (0.00720) [0.47155]
D(LNK(-2))	**0.006995** (0.02281) [0.30665]	**0.3885443** (0.08755) [-1.89124]*	**-0.092453** (0.20432) [-0.45249]	**0.901482** (0.00991) [1.95648]*	**0.206332** (0.0678) [1.93358]*
D(LNT(-1))	**-0.296613** (0.10317) [-2.9314]***	**-0.353032** (0.268704) [-1.83188]*	**-0.490931** (0.05312) [-1.7625]*	**-0.11380** (0.02637) [3.2209]***	**-0.176068** (0.06381) [-1.89201]*
D(LNT(-2))	**-0.279627** (0.068267) [-1.66715]*	**-0.395712** (0.05107) [2.90361]***	**-0.216154** (0.005712) [1.76432]*	**-0.874599** (7.311246) [-1.19604]	**-0.587574** (0.50039) [-1.17443]
D(LNP(-1))	**0.408262** (0.05683) [1.69479]*	**0.506014** (2.003831) [-3.2313]	**0.69224** (1.02778) [2.35015]	**0.540230** (0.03284) [1.8932]*	**0.103537** (0.09887) [1.89318]*
D(LNP(-2))	**0.393330** (3.02405) [1.33558]	**0.275712** (0.05107) [-2.9366]***	**0.313257** (0.021679 [1.94449]*	**0.15122** (0.07197) [-1.72397]*	**0.81345** (0.71967) [1.13031]
CONTANT	**0.277630** (0.01191) [2.65178]**	**0.12534** (0.015013) [1.83494]*	**-0.027995** (0.10667) [-0.26244]	**0.74551** (0.00518) [1.89440]*	**0.055176** (0.00165) [-1.6980]*
R-squared:	0.410892	0.635062	0.645321	0.556331	0.55529
Adj-R^2:	0.161654	0.480665	0.495264	0.368625	0.36744

AIC:	-2.197499	-2.870707	-2.18703	-3.86429	-4.623348
Schwaz SC:	-1.680367	-3387839	-2.704435	-3.347167	-4.106216
Notes: ( ) represents standard error, [ ] represents t-statistics;*/**/***= significant at 10 percent, 5 percent and 1 percent with critical value of 1.697, 2.042 and 2.750 respectively.					

Source: Author's Estimation Results, (2011).

Table 31: Results of the VECM Estimate on Nigeria's Maximum Climatic Dataset

SYSTEM EQUATIONS					
Variable	D(LN Y)	D(LNL)	D(LNK)	D(LNT)	D(LNP)
ECT	**-0.387010** (0.02372) [-1.69710]*	**-0.584658** (0.14137) [-2.41296]**	**-0.479029** (0.191752) [2.49814]**	**-0.253915** (0.00461) [-5.49892]***	**-0.18192** (0.177048) [-0.66757]
D(LNY(-1))	**0.401161** (0.26335) [1.52911]	**0.020957** (0.45749) [-0.04581]	**0.309632** (0.012008) [-1.95109]*	**0.129993** (0.05105) [2.54622]**	**-0.631619** (1.95751) [-0.32266]
D(LNY(-2))	**-0.129922** (0.23082) [-0.56287]	**0.453273** (0.040252) [-1.89610]*	**0.397138** (0.18653) [2.69540]**	**0.032770** (0.04492) [0.72956]	**-0.541436** (1.72228) [-0.31437]
D(LNL(-1))	**0.149867** (0.02901) [2.161657]**	**0.165675** (0.002249) [-7.36291]***	**-0.277269** (0.04256) [-1.99247]*	**0.131703** (0.02511) [5.24592)***	**-0.900696** (1.72228) [-0.31437]
D(LNL(-2))	**0.339260** (0.06225) [2.54495]**	**0.733951** (0.10855) [-6.76120]***	**-0.566131** (0.50305) [-1.12540]	**0.045792** (0.01211) [3.78019]***	**-0.266791** (0.46448) [-0.57439]
D(LNK(-1))	**0.001809** (0.02179) [0.08299]	**-0.034747** (0.03801) [-0.91426]	**-0.478326** (0.17612) [-2.71594]**	**0.002606** (0.00424) [-0.614381]	**0.599790** (0.16626) [2.36884]**
D(LNK(-2))	**0.001348** (0.02180) [-0.06185]	**0.36889** (0.00380) [1.97054]*	**0.207079** (0.017614) [1.90537]*	**0.00080** (0.00424) [0.18761]	**0.104339** (0.001626) [2.64157]**
D(LNT(-1))	**-0.312672** (0.01088) [2.14843]**	**-0.589026** (0.093314) [-2.89116]***	**-0.261789** (0.08953) [-1.8001]*	**-0.449013** (0.21573) [1.98870]*	**-0.631260** (1.827148) [-0.78318]
D(LNT(-2))	**-0.306254** (0.06518) [-2.48980]*	**-0.210893** (0.01367) [-1.85518]*	**-0.366493** (0.52679) [-0.6970]	**-0.04079** (0.12686) [-0.32161]	**-0.722015** (0.08271) [-1.8440]*
D(LNP(-1))	**0.24173**	**0.014846**	**0.084547**	**0.00986**	**-0.648034**

	(0.02587) [-1.93424]*	(0.04512) [0.32903]	(0.002091) [-1.94043]*	(0.00504) [1.96006]*	(0.19306) [-3.3566]***
D(LNP(-2))	**0.045926** (0.02782) [1.67366]*	**0.012690** (0.04852) [0.26155]	**0.511692** (0.022484) [-6.74670]***	**0.004055** (0.00541) [0.74887]	**-0.438229** (0.20760) [-2.11096]**
CONTANT	**0.00956** (0.01407) [0.67985]	**0.073789** (0.02454) [-3.00733]***	**0.035868** (0.00274) [0.31545]	**0.080331** (0.00274) [3.04251]***	**-0.438229** (0.20760) [-2.17096]**
R-squared:	0.242480	0.943513	0.616484	0.755040	0.461550
Adj-R^2:	0.078010	0.919614	0.454227	0.651403	0.233744
AIC:	-1.946059	-0.833883	-0.23004	-5.219676	-2.073450
Schwarz SC:	-1.428927	-0.316751	-2.75136	-4.702543	-2.590582
Notes: ( ) represents standard error, [ ] represents t-statistics;*/**/***= significant at 10 percent, 5 percent and 1 percent with critical value of 1.697, 2.042 and 2.750 respectively.					

Source: Author's Estimation Results, (2011).

Rows six and seven report capital input to cocoa production with positive coefficient, but statistically insignificant suggesting that, with the maximum values in Nigeria's case, cocoa output does not momentously depend on fertilizer input. This result is analogous to that of table 30 where the lags of capital inputs were dropped from the over-parameterized model. In other words, they were not part of the final parsimonious model.

The eighth row and ninth row show the effect of temperature on cocoa output for Nigeria using the maximum values. Whereas row eight reports one year lag of temperature, row nine displays the two year lag of temperature. Both variables are significant and with negative regression coefficients. The significance of the coefficient connotes that cocoa output in Nigeria depends on previous temperature inputs. This, put differently, implies current cocoa output is as a result of previous temperature inputs. This particular result suggests that 1.0 percent change in a year and two years beyond the stipulated requirement will reduce cocoa output by 0.312 percent and 306 percent respectively. This result is a buildup of the ECM results of Nigeria maximum climatic value estimation in that the parsimonious results did not have these lags as reflected in this VECM results.

Table 31 is one year lag and a two year lag of precipitation with significant positive coefficient values. The significant coefficient values suggest that precipitation influences cocoa output in Nigeria. Therefore, a 1.0 percentage change in previous year as well as two years' precipitation will result in an increase of cocoa output by 0.241 percent and 0.049 percent respectively. Precipitation from the ECM approach for Nigeria's maximum values was insignificant. This result, therefore, is crucial as it digs further on the lag effects of precipitation for Nigeria's case.

Table 32 reports the results of Ghana's mean climatic VECM estimates. The ECT coefficient of -0.378 suggests that in Ghana's case, using the mean values, deviations from the preceding year's equilibrium is corrected by 38% at current year. This speed of adjustment though lower than the results of the ECM for Ghana means, it is still very closes (43%).

Row four and row five account for the lag effects of labour input to cocoa production in Ghana. Both have significant positive coefficients indicating that lag effects are monumental in cocoa output in Ghana's case. The result shows that 1.0 percent change in a year's labour input and two years' labour input will increase cocoa output by 0.206 percent and 0.002

respectively. This result is also paramount in the sense that when the result is compared to the mean estimates of the ECM, it gives additional information to the previous which would have otherwise been lost.

Further, rows six and seven describe the results of one year and two years capital input to cocoa production in Ghana. Both coefficients are positive and significant suggesting that cocoa output depends on past use of capital input. In this case, a 1.0 percent change in one year and two years capital input will increase cocoa output in the present year by 0.211 percent and 397 percent respectively, holding all other variables in the model constant. In the ECM approach, one year lag of capital was equally significant, but two years lag was absent from the final report. This result, therefore, strengthens the previous finding.

One year lag of temperature and two years lag of temperature are reported in rows eight and nine. Both coefficients are negative and significant. This suggests that 1.0 percent change in temperature beyond the tipping point will reduce cocoa output by 0.228 percent and 204 percent respectively. The one year lag result is opposite to the result obtained from the ECM approach on Ghana's mean values.

On Ghana's mean estimates are the results of a year's lag and two years lag of precipitation to cocoa output. Both coefficients are significant and positive indicating that cocoa output in Ghana largely depends on past precipitation as input. The result shows that 1.0 percent change in one and two years precipitation will increase cocoa output by 0.356 percent and 0.140 percent respectively. The one year result corroborates that of ECM result for Ghana but opposite to the result on two years lag of precipitation which was insignificant in the former case.

Table 33 reports the results of the VECM estimates on Ghana's maximum climatic values. By comparison, the ECT in this estimation is lower than the ECM result on Ghana's maximum climatic values. Whereas the ECM results report 71% of adjustment, the VECM records 67%. The reason could be due to the assumptions underlying the methods used in each case. In terms of interpretation, the ECT suggests that the preceding period's disequilibrium is corrected for by about 67% annually.

Table 32: Results of the VECM Estimate on Ghana's Mean Climatic Dataset

SYSTEM EQUATIONS					
Variable	D(LN Y)	D(LNL)	D(LNK)	D(LNT)	D(LNP)
ECT	**-0.37838** (0.04702) [1.69683]*	**-0.257674** (0.057138) [2.45097]**	**-0.201966** (0.01706) [-1.78276]*	**-0.210443** (0.01166) [2.23830]**	**-0.308693** (0.35037) [0.88105]
D(LNY(-1))	**-0.01350** (0.19057) [0.05431]	**0.12227** (2.31552) [0.05279]	**-0.160930** (0.06915) [-1.96765]*	**-0.72518** (0.04727) [-1.76743]*	**0.199020** (0.04198) [1.88723]*
D(LNY(-2))	**-0.500336** (0.20566) [-2.43289]**	**0.104839** (2.29886) [0.41977]	**-0.201985** (0.07463) [-2.70659]**	**-0.137787** (0.05101) [-2.70128]**	**-0.561765** (1.53229) [0.36662]
D(LNL(-1))	**0.206295** (0.01548) [3.40657]***	**0.467301** (0.18812) [-2.48406]**	**0.072792** (0.00562) [1.767205]*	**-0.001888** (0.05101) [-0.49179]	**-0.54883** (0.11535) [-1.74582]*
D(LNL(-2))	**-0.002454** (0.01531) [2.16037]**	**0.262028** (0.18597) [1.84094]*	**0.002351** (0.00380) [-0.62422]	**-0.230351** (0.00380) [-2.61922]**	**0.626310** (0.11404) [2.54922]**
D(LNK(-1))	**-0.211352** (0.01537) [1.86035]*	**0.238354** (0.23273) [0.10250]	**-0.166747** (0.06953) [-2.39909]**	**-0.114548** (0.475061) [-2.40085]**	**0.602631** (0.142709) [1.821996]*
D(LNK(-2))	**-0.39706** (0.193325) [1.76051]*	**-0.49555** (1.23490) [1.78608]	**-0.7441896** (0.701525) [-1.06082]	**-0.505467** (0.047949) [-1.85417]*	**0.431088** (1.44041) [-0.99353]
D(LNT(-1))	**-0.228002** (0.027685) [1.802352]*	**-0.285518** (0.13574) [2.08208]**	**-0.230398** (0.10705) [2.29780]**	**-0.576093** (0.068534) [2.29971]**	**-0.49625** (0.20587) [1.72410]*
D(LNT(-2))	**-0.204893** (0.027853) [1.826469]*	**-0.67454** (0.03844) [1.79484]*	**-0.101748** (0.71705) [2.01067]	**-0.691063** (0.690850) [1.00031]	**-0.20108** (0.02533) [1.96854]*
D(LNP(-1))	**0.35675** (0.002821) [1.96469]*	**-0.175046** (0.34275) [1.40864]	**0.194419** (0.01024) [1.940864]*	**0.144190** (0.00700) [1.741255]*	**-0.504740** (0.21017) [-2.40152]**
D(LNP(-2))	**0.140453** (0.02743)	**-0.054139** (0.16220)	**0.114419** (0.00484)	**-0.302148** (0.00680)	**-0.261525** (0.020439)

	[1.762331]*	[0.81947]	[1.75214]*	[-2.94627]***	[-1.72795]*
CONTANT	**-0.007758** (0.01335) [0.58116]	**0.132919** (0.16220) [0.81947]	**0.706815** (0.00484) [1.75214]*	**0.052900** (0.00351) [1.957651]*	**-0.25834** (0.09946) [2.59740]**
R-squared:	0.259943	0.574011	0.611382	0.611247	0.475476
Adj-R^2:	0.053154	0.393785	0.446967	0.446774	0.255620
AIC:	-1.969182	-3.025392	-3.996728	-4.757826	-2.047247
Schwarz SC:	-1.452249	-3.542525	-3.479649	-4.280693	-2.564337
Notes: ( ) represents standard error, [ ] represents t-statistics;*/**/***= significant at 10 percent, 5 percent and 1 percent with critical value of 1.697, 2.042 and 2.750 respectively.					

Source: Author's Estimations Results, (2011).

Table 33: Results of the VECM Estimate on Ghana's Maximum Climatic Dataset

SYSTEM EQUATIONS					
Variable	D(LN Y)	D(LNL)	D(LNK)	D(LNT)	D(LNP)
ECT	**-0.674133** (0.109107) [-1.94347]*	**-0.56044** (0.01109) [-3.05882]***	**-0.358901** (0.15921) [1.69195]*	**-0.216712** (0.03817) [-5.67765]***	**0.231701** (0.034560) [1.69704]*
D(LNY(-1))	**-0.252196** (0.23658) [1.66010]	**-0.10191** (0.01373) [2.07430]**	**-0.275964** (1.97829) [-1.39451]	**0.125244** (0.04726) [2.65001]**	**-0.229417** (0.42792) [-0.53612]
D(LNY(-2))	**-0.282855** (-0.20542) [-1.37696]	**-0.050030** (0.01193) [-0.421831]	**0.415430** (1.71829) [-0.41841]	**-0.333807** (0.069417) [4.48087]***	**-0.278284** (0.062852) [-2.44276]**
D(LNL(-1))	**0.664424** (0.03748) [1.912091]*	**0.101777** (0.01027) [-1.875045]*	**0.121664** (0.012906) [2.041841]**	**0.333807** (0.04104) [1.748087]*	**0.278249** (0.62852) [-0.44276]
D(LNL(-2))	**-0.473372** (3.56406) [-0.13282]	**0.064329** (0.20690) [0.30657]	**-0.326172** (0.09812) [-1.90408]*	**-0.332629** (0.071199) [-2.06718]**	**0.255137** (0.64664) [0.39577]
D(LNK(-1))	**0.221080** (0.02094) [3.05294]***	**0.606630** (0.01022) [1.75468]*	**0.598208** (0.97512) [-3.41605]	**0.002434** (0.00418) [-0.58196]	**0.08044** (0.03787) [2.21243]**
D(LNK(-2))	**0.077200** (0.02126) [2.36303]**	**0.176064** (0.01236) [1.761911]*	**0.114619** (0.009644) [1.923441]*	**0.91E-05** (0.177887) [-2.64441]**	**0.08522** (0.03845) [0.22156]
D(LNT(-1))	**-0.789861** (0.084078) [1.99344]*	**-0.36786** (0.04881) [4.75366]***	**-0.247160** (0.03290) [-1.835145]*	**-0.082986** (0.016796) [0.49409]	**-0.401614** (0.05208) [2.26408]**
D(LNT(-2))	**-0.50037** (0.03577) [1.98891]*	**-0.48023** (0.03238) [-1.76276]*	**-0.240049** (4.66541) [-051548]	**-0.107283** (0.11142) [-0.96285]	**-0.123482** (0.010885) [1.922399]*
D(LNP(-1))	**0.20434** (0.10981) [2.18609]**	**-0.004863** (0.00637) [-0.76280]	**-0.327331** (0.09185) [1.88057]*	**0.075862** (0.02194) [-3.45827]***	**0.112907** (0.01986) [-5.65842]***
D(LNP(-2))	**0.094566** (0.12696) [0.74437]	**0.26776** (0.00737) [1.91934]*	**0.209414** (0.06199) [1.97498]*	**-0.096737** (0.02536)	**-0.166082** (0.22965) [-0.72312]

				[- 2.74955]***	
CONTANT	**0.17880** (0.05731) [1.73980]*	**0.100912** (0.00335) [3.27985]***	**0.549985** (0.47938) [1.14728]	**0.011471** (0.011471) [1.00197]	**0.302987** (1.10366) [-2.28819]
R-squared:	0.295585	0.18114	0.618045	0.760038	0.833886
Adj-R^2:	0.02057	0.166761	0.456448	0.658516	0.763607
AIC:	-2.019121	-7.711955	-2.228925	-5.240290	-0.833803
Schwarz SC:	-1.501988	-7.194822	-2.746058	-4.723158	-0.316670
Notes: ( ) represents standard error, [ ] represents t-statistics;*/**/***= significant at 10 percent, 5 percent and 1 percent with critical value of 1.697, 2.042 and 2.750 respectively.					

Source: Author's Estimation Results (2011).

The fourth and fifth rows display one year lag and two years lag of labour input to cocoa production in Ghana. Whereas both coefficients are positive, the one year lag is significant and the two years lag is not. The non-significance of the two years lag suggests that, in Ghana's case and in line with the maximum data set, two years labour input does not affect cocoa output. The significant of the regression coefficient of the one year lag suggests that a 1.0 percent change in labour input in the preceding year will increase cocoa output by 0.664 percent. With the ECM approach, the lag effects of labour were not part of the final model and therefore, the current report is a beef-up of the previous result.

Rows six and seven report a year and two years lag of capital input to cocoa production in Ghana with positive significant coefficient values. The significance of these coefficients suggests that capital input is relevant in cocoa production in Ghana. Consequently, 1.0 percent change in capital input in both periods increases cocoa output by 0.221 percent and 0.077 percent, holding all other regressors' value constant. This result coincides with the maximum value estimation under the Engle-Granger's error correction approach used for Ghana.

Rows eight and nine of table 5.9(d) reflects a year lag and two years lag of temperature input in the production process of cocoa in Ghana. The results show that both coefficients are negative and significant. As such, a 1.0 percentage change in temperature input over the required quantity (can be viewed as shocks) in the preceding year and two years decreases cocoa output at the present year by 0.789 percent and 0.500 percent respectively. By comparison, the ECM on Ghana's maximum value did not have the lags of temperature in the final model and so this result can be viewed as an upgrade of the previous result.

Ghana's case on a-two year lag and a year lag of precipitation as input to cocoa production is recorded in row ten and eleven with positive coefficient values. While a year lag is significant, the two years lag is insignificant and what this means is that a two year precipitation does not affect current cocoa output, but one year does. This, therefore, suggests that a 1.0 percent change in previous year's precipitation increases cocoa output by 0.204 percent, holding all other things equal. Comparing this outcome with the ECM results for Ghana, it is obvious that while the two year result differs, the one year lag result corroborates with exactness in the regression coefficient.

Cote D'Ivoire's results on both minimum and maximum climatic values are reported in tables 34 and 35 respectively. Taking the former, it is clear from the first row that the error correction mechanism is very high implying high speed of adjustment after deviations from equilibrium. This adjustment parameter is the highest among all the three countries studied. What this result means is that about 82% of the previous year's disequilibrium is corrected for in the current year.

The fourth and the fifth rows report a year's lag of labour and two years lag of labour respectively. The regression coefficients are both positive but significant for only a year's lag and insignificant for the two years case. The coefficient for a year lag of labour suggests that a 1.0 percent change in the preceding years labour will increase cocoa output by 0.299 percent in the current year, all other factors held constant. This result is an improvement of the ECM approach on Cote D'Ivoire's mean estimation result above.

Rows six and seven describe a one year lag of capital and a two year lag of capital respectively. While the two year lag of capital with positive coefficient value is insignificant, the one year lag is significant. What this result means is that a 1.0 percent change in the preceding year's capital input will increase cocoa output by 0.299 percent in current year. This result while adding to the result of the mean value estimation on Cote D'Ivoire in terms of one year lag, disagrees with the result on the two year lag.

With the mean values a year and two years' lag of temperature do not impact on cocoa output in Cote D'Ivoire. As reported in the eighth and ninth row, their coefficient values are insignificant and negative. This result is opposed to row nine, table 34 of Cote D'Ivoire's mean estimation results using the Engle Granger's approach. However, it strengthens the one year lag result on temperature in Cote D'Ivoire.

On Cote D'Ivoire mean estimate result, is a year and two years lag on precipitation as recorded in rows ten and eleven respectively. The results suggest that a 1.0 percent change in a year and two years' precipitation will increase cocoa output by 0.378 percent and 0.574 percent respectively.

Table 34: Results of the VECM Estimate on Cote D'Ivoire's Mean Climatic Dataset

SYSTEM EQUATIONS					
Variable	D(LN Y)	D(LNL)	D(LNK)	D(LNT)	D(LNP)
ECT	**-0.829657** (0.15807) [1.71618]*	**-0.190194** (0.00171) [-2.11374]**	**-0.288987** (0.025054) [-1.911534]*	**-0.170010** (7.00554) [-3.18165]	**-0.346099** (0.056651) [6.12419]***
D(LNY(-1))	**-0.232718** (0.73232) [-2.31778]**	**0.017785** (0.02156) [-0.82502]	**0.160047** (0.015954) [-3.67160]***	**0.083840** (0.06991) [1.91926]*	**0.3138701** (0.71270) [-0.93562]
D(LNY(-2))	**0.299207** (0.06532) [1.745770]*	**0.09224** (0.01924) [-2.48294]**	**-0.160047** (2.82046) [-0.41843]	**0.15767** (0.06241) [1.92526]*	**0.595252** (0.06322) [1.93562]*
D(LNL(-1))	**0.299209** (0.10653) [-2.65348]**	**0.651831** (0.24367) [2.67551]**	**-0.108781** (3.57130) [-0.30460]	**0.582864** (0.17902) [1.73612]*	**-0.35284** (0.05621) [-4.38004]***
D(LNL(-2))	**-0.469126** (9.47116) [-0.02332]	**0.270862** (0.27881) [0.97150]	**0.220384** (0.04862) [-1.98953]*	**0.709166** (0.090416) [1.767843]*	**0.370769** (0.089317) [-2.00832]*
D(LNK(-1))	**0.28325** (0.04835) [1.78578]*	**0.400421** (0.00142) [2.29558]**	**0.417681** (0.10286) [-2.0028]*	**0.07857** (0.00462) [-1.7020]*	**0.737694** (0.93174) [-0.44280]
D(LNK(-2))	**0.42718** (0.05857) [-3.17636]	**0.08911** (0.00142) [-1.71109]*	**-0.81796** (0.201862) [0.44112]	**0.62497** (0.10419) [3.01186]***	**-0.067817** (0.01427) [-1.85866]*
D(LNT(-1))	**-0.176311** (3.55774) [0.04956]	**-0.085886** (0.10473) [0.81989]	**-0.26498** (0.01534) [-2.93424]**	**-0.31730** (0.13961) [-1.97342]*	**-0.17691** (0.03462) [5.10946]***
D(LNT(-2))	**-0.68961** (1.06181) [1.50597]	**-0.20576** (0.10551) [1.99305]*	**-0.16559** (0.01561) [-1.98605]*	**-0.39159** (0.04540) [-2.83773]**	**-0.14533** (0.03521) [4.12742]***
D(LNP(-1))	**0.378790** (0.17643) [2.44612]**	**0.64042** (0.00519) [1.86332]*	**0.14823** (0.07611) [-1.94746)*	**0.04507** (0.01684) [-2.02675]**	**0.16897** (0.01717) [1.93865]*
D(LNP(-2))	**0.57410** (0.17308)	**0.01429** (0.0501)	**0.39482** (0.07064)	**0.08375** (0.01652)	**0.39406** (0.16844)

	[1.83317]*	[0.280567]	[3.14037]***	[-0.50686]	[1.74579]*
CONTANT	**0.42850** (0.06354) [2.6684]**	**0.03920** (0.00187) [1.90540]*	**0.23739** (0.02734) [1.75660]*	**0.40330** (0.00607) [-2.71430]**	**0.297297** (0.06184) [4.80774]
R-squared:	0.342251	0.733596	0.589937	0.412888	0.918881
Adj-R^2:	0.063973	0.620887	0.416449	0.164474	0.884561
AIC:	-0.468212	-7.519179	-2.455729	-5.166213	-0.522514
Schwarz SC:	-0.048921	-7.002047	-2.972862	-4.649080	-0.005381
Notes: ( ) represents standard error, [ ] represents t-statistics;*/**/***= significant at 10 percent, 5 percent and 1 percent with critical value of 1.697, 2.042 and 2.750 respectively.					

Source: Author's Estimations Results, (2011).

Table 35 reports the VECM estimation results of Cote D'Ivoire. A closer examination of the table indicates that the error correction term is lower than the mean value recorded above. This result follows the same pattern as in the case of the Engle Granger's approach. In those results, though they differ in terms of figures, the speed of adjustment is higher with the mean values, but reduces with the maximum values. This particular result suggests that deviations from equilibrium are corrected at about 57% per annum. In general, all the variables have significant effects on cocoa output.

Rows four and five reports a year and a two year lag of labour input to cocoa production in the Ivorian economy. The results show positive and significant coefficient values suggesting that a 1.0 percentage change in a year and two years will increase cocoa output by 0.184 percent and 303 percent respectively, holding all other factors constant. This result can also be viewed as a top up of the ECM approach as there was no lag terms for labour in the final model for reporting.

Lag effects of capital input to cocoa production are expressed in rows six and seven. The coefficients of a year lag and two years lag are positive and significant suggesting that 1.0 percent change in these variables will increase cocoa output by 0.496 percent and 403 percent respectively. This result confirms the second year lag report but adds essence to the one year lag result of the ECM.

A year lag and two years lag of temperature are next in row eight and nine in that order. They are both positive contrary to expectation and significant in terms of their regression coefficients. What this means is that 1.0 percent change in any of the two variables will result in 0.498 percent and 0.345 percent increase in cocoa output correspondingly. This result, a part from its positive sign which makes it unique in all the results, also supports the two years lag result of the ECM and a top up of the information on the one year lag.

Table 35: Results of the VECM Estimate on Cote D'Ivoire's Maximum Climatic Dataset

SYSTEM EQUATIONS					
Variable	D(LN Y)	D(LNL)	D(LNK)	D(LNT)	D(LNP)
ECT	**-0.578115** (0.04707) [1.966965]*	**-0.24450** (1.11670) [1.72379]	**-0.143412** (0.04030) [2.35583]**	**-0.219976** (0.01708) [1.82682]*	**-0.306475** (0.03507) [1.87368]*
D(LNY(-1))	**0.10881** (0.01905) [2.57100]*	**0.072610** (0.04726) [-1.69534]*	**0.191893** (0.06317) [1.731160]*	**-0.106224** (0.09614) [1.53630]	**-0.127590** (0.01422) [1.85029]*
D(LNY(-2))	**0.499530** (0.20566) [-2.42888]**	**-0.137729** (0.05101) [-2.70030]**	**-0.1026317** (1.76107) [1.58278]	**0.201900** (0.07462) [-2.28361]**	**-0.558883** (1.53278) [-0.36462]
D(LNL(-1))	**0.184860** (0.07726) [3.6667]***	**0.257169** (0.08762) [2.28560]**	**0.412366** (2.37418) [-0.17369]	**0.229736** (0.06020) [2.28361]**	**0.497245** (2.06644) [0.24063]
D(LNL(-2))	**0.303022** (0.19538) [1.72631]*	**0.690995** (0.03926) [1.99671]*	**0.450578** (0.01239) [-1.88238]*	**0.101733** (1.01428) [1.00301]	**0.200748** (0.08336) [1.96358]*
D(LNK(-1))	**0.49613** (0.0220) [3.43520]***	**0.626013** (0.05548) [-0.47705]	**0.467534** (2.18915) [-2.47174]	**0.303386** (4.20802) [-1.874819]	**0.76883** (0.16463) [1.76900]*
D(LNK(-2))	**-0.40305** (0.02179) [-1.91324]*	**0.03247** (0.00541) [0.00541]	**0.263058** (0.018663) [1.840953]*	**-0.47090** (0.07910) [4.60566]***	**0.18692** (0.01624) [1.95351]*
D(LNT(-1))	**0.49819** (0.12252) [1.90351]*	**0.11377** (0.01476) [-2.38620]**	**0.323675** (0.061642) [1.91662]*	**-0.16631** (0.80096) [-2.38428]	**0.31547** (0.10432) [1.78922]*
D(LNT(-2))	**0.34576** (0.09408) [-3.75104]***	**0.50570** (148132) [-1.95065]*	**0.31206** (0.16618) [-1.8778]*	**-0.74450** (0.17419) [-1.70572]*	**0.142835** (0.01446) [1.98747]*
D(LNP(-1))	**0.30543** (0.02882) [1.72659]*	**0.09885** (0.00699) [1.94880]*	**0.193814** (2.02414) [3.88551]	**0.14384** (0.10230) [1.48590]	**-0.50499** (0.021015) [-2.440303]**

D(LNP(-2))	**0.54431** (0.27370) [1.67250]*	**0.20032** (0.06079) [-2.47467]**	**0.81399** (0.11429) [2.71221]**	**0.17591** (0.00981) [1.88352]*	**-0.025517** (0.09948) [-0.25652]
CONTANT	**0.17682** (0.01325) [2.57553]**	**0.05273** (0.00331) [1.59293]	**0.81399** (0.11429) [0.71221]	**0.70591** (0.00881) [1.77435]*	**-0.670055** (0.009948) [4.25652]***
R-squared:	0.25950	0.611085	0.579068	0.611223	0.478864
Adj-R^2:	0.15370	0.446544	0.400981	0.446740	0.2526691
AIC:	-1.968785	-4.757410	-2.326092	-3996371	-2.048413
Schwarz SC:	-1.451653	-4.240277	-2.843225	-3.479239	-2.565546
Notes: ( ) represents standard error, [ ] represents t-statistics;*/**/***= significant at 10 percent, 5 percent and 1 percent with critical value of 1.697, 2.042 and 2.750 respectively.					

Source: Author's Estimations Results, (2011).

Finally, the lag effects of precipitation are also apparent on rows ten and eleven. Whereas row ten reflects one year lag of precipitation as an input to cocoa production, row eleven covers a two year lag effects of precipitation. Both variables are significant and positive in coefficients, suggesting that cocoa output strongly depends on the lag inputs of precipitation. 1.0 percent change in a year and two years lag of precipitation will accordingly increase cocoa output by 0.305 percent and 0.544 percent respectively. This result is akin to the one year lag report of Cote D'lvoire under the ECM approach and strengthens the result of the two years lag of precipitation.

5.6. Discussion of Results

This section discusses and analyses the major results in the thesis upon which conclusions are drawn for policy recommendations in the next chapter. The results have been arranged according to the various estimations that were undertaken in this thesis.

5.6.1. Panel Results

The panel study considered eight cocoa producing countries in West Africa to ascertain whether climate change has impact on their output. Major climatic variables, namely temperature and precipitation, capable of influencing cocoa production were considered alongside other leading inputs for the analysis. Both mean and maximum values of these variables were considered separately for the analysis.

Regarding the estimation on the mean climatic values, it is clear that cocoa production directly and significantly depends on labour input in West Africa. The implication is that cocoa output in the sub-region could increase if labour input is increased in the cocoa sector. This result is similar to the conclusion drawn by Lundstedt et al, (2009) that cocoa is labour intensive.

With the mean values, capital input was found not to be significant suggesting that cocoa output does not momentously depend on fertilizer input in the Sub-region. In a likewise manner, the mean temperature values did not show any significant impact on cocoa production in West Africa. The inference here is that cocoa grows well within a particular range of temperature. Beyond the required range, temperature input tends to negate cocoa production. This implies the mean values are still within the range for which reason its impact is not felt.

This supports the conclusions drawn by Ajewole *et al,* (2010) that there is positive weak correlation between cocoa yield and temperature in Nigeria.

In terms of Precipitation, it positively and significantly supports cocoa production in West Africa. Whereas this result is in line with the findings of Anim-Kwapong et al (2004), it is contrary to the results of Ajewole *et al,* (2010).

Moreover, precipitation, though as individual input has a positive coefficient, when combined with labour, they together exhibit negative relationship. However, their combined interaction significantly affects cocoa production in West Africa. This implies that while precipitation serves as a catalyst to cocoa production, its constant flow and or excesses tend to reduce the effectiveness of labour input in the production process thereby negating cocoa production.

The combined interaction of capital (Fertilizer input) and temperature is negative to cocoa production, suggesting that even in the wake of abundance application of fertilizer cocoa may not grow up well if temperature is in excess of what is required. This suggests that the blend of growth input and facilitating inputs in their rightful proportions are of good support to cocoa production. This corroborates with the findings of Lawal *et al* (2007), that a combination of optimal temperature, minimal rainfall and relative humidity will give a better yield.

Finally on the mean value estimation results, temperature and precipitation do have lag effects on cocoa production. While a year lag of precipitation impacted positively on cocoa production, a-three year lag of temperature impacts negatively on cocoa production in West Africa. These facts support Guan's (2006) assertion that, unlike arable crops, tree crops do not have instantaneous effect of climatic fluctuations.

With the panel maximum value estimation, unlike the mean values, both capital and labour significantly contribute positively to cocoa production in West Africa. The implication is that as temperature increases and precipitation falls, more of labour and fertilizer input become very relevant in the production process of cocoa in West Africa. Unlike the mean values, the maximum values suggest that the two main climatic variables do have substantial impact on cocoa production. While temperature is negatively impacting on cocoa output, precipitation is having a positive effect on cocoa production in West Africa. This outcome corroborates with many of the studies done in a localized form within West Africa such as Anim-Kwapong et al, (2004) in Ghana, Oyekale *et al,* (2009) in Nigeria, and Nhemachena (2006) in Zimbabwe as well as Ajewole *et al* (2010), Nigeria.

Also, the maximum estimation result is that, the interaction of labour and precipitation is considered good for cocoa production in West Africa. However, the result suggests that one of them has a reducing effect on the other. At best, their blend in their rightful proportions would lead to efficient use in the production process of cocoa. In the same vein, the interaction of capital (fertilizer) and temperature suggests that extreme temperature does not combine well with fertilizer application. The implication is that fertilizer application during high periods of temperature would reduce the effectiveness of its application thereby negatively impacting on cocoa output.

Finally, the panel result is the lag effects of temperature and precipitation which are shown by the results as apparent in the Sub-region as having impact on cocoa production. The result suggests that temperature's negative effect lingers up to a three year lag on cocoa output. Precipitation, however, positively impacts on cocoa output up to a year effect. This finding confirms Guan's (2006) assertion as cited extensively in this thesis.

5.6.2. The simulation results

Regarding the second empirical objective, a simulation in the form of high sensitivity analysis was undertaken to ascertain the future state of the cocoa industry in the wake of climate apprehension.

The first scenario result indicates that with decreasing temperature and increasing precipitation will lead to an increase in cocoa output. However, the rate of change increases, becomes constant and diminishes.This suggests that extreme weather condition that would lead to temperature declining with increasing precipitation will only lead to a transitory increases in cocoa output which will eventually get fade out.

The second scenario result implies that with constant temperature at the 2009 historical data, and falling precipitation will lead to declining cocoa output suggesting that the blend of these climatic variable inputs are very essential. This substantiates the findings of Lawal *et al* (2007), that a combination of optimal temperature, minimal rainfall and relative humidity will give a better yield.

The third scenario encapsulates a falling trend in both temperature and precipitation which results in declining cocoa output. The description is that, a falling temperature and a falling precipitation do not augur well for cocoa production in the sub-region. This outcome agrees to Emaku *et al* (2007).

The fourth scenario examines the constant precipitation and falling temperature which result in increasing cocoa output over the period. However, the rate of change of the output growth is very marginal. What this result means is that pegging precipitation at its 2009 historical data and envisioning a declining temperature will bring about increses in cocoa output. The expected rate of change is woefully inconsequential for the sub-region.

Scenario five unfolds instances where temperature rises with increasing precipitation which results in increases in cocoa output. The anticipated increases are, however, at diminishing rate. This graceless pixture suggests that rising temperature in the presence of increasing precipitation can only be viewed as a transitory event in West Africa.

The final one is the most probable among all the unpleasnt scenarios and this mirrors the current state of the event according to the IPCC (2007), UNDP(2009) and so on. It foresees a rising temperature and a falling precipitation. The result indicates that cocoa output will fall depending on the actual rate of the falling and rising trajectory of these variables. This result is threating and suggests that cocoa output in the Sub-region faces serious threat in the nearest future if nothing is done to mitigate or adapt to climate change.

5.6.3. The country specific ECM estimation results

A thoughtful observation of the estimations carried out under the ECM shows that the speed of adjustment following previous disequilibrium differs from one country to another. Table 36 below gives a sharp comparison of the speed of adjustment for the respective countries. An examination of the table shows that with the minimum value estimation, Ghana has the lowest speed of adjustment suggesting that realignment towards equilibrium takes longer time than the other countries. This could possibly be due to the country characteristics such as population size, resources, labour skills and other intangible factors. Interestingly, Ghana has the largest speed of adjustment when it comes to using the maximum value results. Cote D'Ivoire unfortunately has the lowest speed of adjustment geared towards equilibrium after proceeding years' of distortions when maximum value results are compared. This striking result suggest that, in line with the scientific projections given on temperature and precipitation, Cote D'Ivoire and Nigeria are likely to be more affected since their speed of adjustment is lower with maximum climatic values.

Table 36: Country Comparison of the adjustment coefficients of the ECM Estimation

Country	Minimum Value Estimation	Maximum Value Estimation
Nigeria	-0.671087	-0.568292
Ghana	-0.434610	-0.712734
Cote D'Ivoire	-0.828318	-0.390203

Source: Author's estimation results (2011).

Another important pattern observed from table 36 is that, except in Ghana's case, the speed of adjustment reduces with the maximum value estimation when compared to the minimum estimation results. This suggests that as climatic factors move towards extreme cases, the less or slower realignment towards equilibrium becomes.

In terms of the other variables in the parsimonious model, it is expedient to state that their significant levels, size and signs strongly differed from one country to the other and more so from using the mean and maximum climatic values. However, there was a general pattern which culminates with the result of the panel study, particularly in Nigeria's case. This pattern includes insignificance of some variables with the use of the minimum values, but significant at the maximum value estimation results. A typical example is capital which was not significant with the mean value estimations, but significant with the maximum value estimation. What can be gleaned from such result is that, as climate moves to the extremes, more of capital (fertilizer) application would be needed in the cocoa sector. This fact corroborates with the panel result.

An attention-grabbing revelation worth discussing is the behavior of temperature across the countries studied. While temperature and its lags were not significant with the minimum values estimation for Ghana, it was significant for Nigeria's case. At the maximum estimation stage, though temperature was significant in both countries, Ghana's significant value was at the high side. Cote D'Ivoire, however, had temperature to be significant at both the maximum and minimum climatic values estimations. What this suggests is that country differences actually exist in terms of these variables and as such supporting the assertion of Shah et al, (2008) that "country specific studies are strongly recommended".

Again, it is worth supporting the above fact on the result of precipitation across these countries. Example, while precipitation is significant at the mean values estimation level for Nigeria, it was not significant at the maximum level. The opposite is realized in Ghana's case. Whereas at the mean estimation level one year lag and two years lag were not significant in Ghana's case, these variables were significant at the maximum level estimation. Cote D'Ivoire however, had precipitation to be significant at all levels of estimation.

Finally, the interactive effects of the variables were significant across all the countries studied. This is so for the interaction of capital and temperature on one hand and labour, and precipitation on the other hand.

5.6.4. The country specific VECM estimation results

The VECM estimation results as summarized in table 37 follow the same pattern as the ECM in terms of the country speed of adjustment arising from previous year's distortions. This time, Nigeria has the lowest speed of adjustment as opposed to Ghana in the ECM estimation result. Generally, the values are lower than that of the ECM and instead have faster adjustment speed in the case of Ghana and Nigeria with the maximum value estimates than in the minimum values estimates. Cote D'Ivoire, however, follows the same pattern of lower speed of adjustment with maximum climatic values as opposed to mean climatic values.

With regard to the specific variables participating in the VECM estimation, it is important to unveil that this report is basically on lag terms of the climatic and other leading variables rather than their normal state variables. Generally, this result agrees with the findings of the ECM with much respect. For instance, while the mean estimation results of the VECM for Nigeria indicates that a year and two year lag of labour is significant that of Ghana shows that a year lag is significant, but two years lag is insignificant. Equivalently, whereas in Nigeria capital input is insignificant at its two years lag using the minimum value results and insignificant at both a year lag and two years lag using the maximum values, Ghana has capital to be significant at a year lag and two years lag.

Also, while a second year precipitation is insignificant from the mean estimation result that of Ghana is significant. The converse is realized with the maximum values estimation results where a second year precipitation is insignificant in Ghana's case, but significant in the Nigeria's case.

In the same way, using the mean values results in the Cote D'Ivoire's case, two year lag of labour, two year lag of capital and, a year and two years precipitation are all insignificant, that of Ghana and Nigeria are all significant (except Nigeria's two years capital).

What can therefore be deduced from the VECM estimation results is that lag effects of climatic variables strongly differ from one country to the other, supporting Shah *et al* (2008) statement that country specific studies are encouraged.

Table 37: Country Comparison of the adjustment coefficients of the VECM Estimation

Country	Minimum Value Estimation	Maximum Value Estimation
Nigeria	-0.2999176	-0.387010
Ghana	-0.378380	-0.674133
Cote D'Ivoire	-0.829657	-0.578115

Source: Author's estimation results, (2011).

5.7. Assessment of results with study objectives

Cocoa output supply of about 70% from West Africa generates US 2 billion dollars annually and contributes significantly to the development of the region's economies via employment, investment and poverty reduction. 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. As a result, the thesis set out two specific objectives to achieve the main objective of examining the current and future impact of climate change on cocoa production in West Africa. The data used for the analysis covered 41 years (spanning 1969 to 2009).

The two specific objectives were:

1 To determine the extent of impact of climate change on cocoa production in West Africa; and

2 To simulate the possible future changes in cocoa production due to climate change under various temperature and precipitation scenarios.

To achieve these specific objectives the crop yield response theory was adopted and based on agronomic ideas derived a second Taylor series transcendental logarithmic production function. Also, from the contextualized part of the study it was crucial to use two sets of data (mean climatic data on one hand and; maximum and minimum climatic data on the other hand) for the analysis. Data from the cocoa producing areas were sourced for the estimation instead of broad country data.

With regards to the first specific objective, both panel and time series econometric methods were used for the estimation process. While the panel regression accounted for the impact of climate change on cocoa production for the sub-regional analysis, the time series regression expounded on the country specific analysis. Also, whereas fixed effect technique was the focus of analysis for the panel study, error correction model by Engle Granger and vector error correction by Johansen were both explored for the country time series analysis. The panel model was estimated utilizing panel data drawn from eight cocoa producing countries in West Africa. These countries are Cote D'Ivoire, Ghana, Nigeria, Togo, Benin, Liberia, Sierra-Leone and Guinea. The time series captured three countries namely; Cote D'Ivoire, Ghana and Nigeria. These three countries jointly supply about 67% of cocoa output. The results from the panel regression formed the basis for the second specific objective. An in-sample simulation that tracked the ability of the model to replicate historical records and for short-run forecasting was used. This formed the basis for carrying out an out-sample simulation for the sub-region utilizing plausible scenarios of various scientific reports. An array of diagnostic tests was conducted to ascertain the potency of the results. These tests included the Hausman test, the Breauch-Pagan Lagrangian Multiplier tests, Residual Normality test comprising of skewness, kurtosis and Jacque-Bera; and Portmanteau test for autocorrelation. It is also important to point out that apart from the two specific objectives the study was as well interested in knowing the significance of the two climatic variables, namely, temperature and precipitation for the sub-region.

- ***Linking the results to the study objectives*.**

A critical evaluation of the results vis-à-vis the study objectives are as follows:

- ❖ Objective One: **"*To determine the extent of impact of climate change on cocoa production in West Africa*"**. The focus was particularly on the size of effect. In this regard, the significance, sign and the size of the coefficient of the estimated regression was very crucial in determining this study objective. From the panel study for cocoa West African countries the two separate regressions utilizing the two data sets had different regression coefficients for temperature and precipitation. Temperature was insignificant with the use of the mean data set and had a coefficient of -0.30. This suggested that, in absolute terms, temperature had no substantial effect on cocoa output in the sub-region. Viewing this result from statistics, one can easily conclude that the absolute low size of -0.30 was an indication that it was barely supporting cocoa growth in the region. Also, bringing the negative coefficient into perspective implied that temperature had a marginal negative effect on cocoa production in the sub-region.

However, in line with the background of the study and the science behind tree crops indicate that the daily requirement of temperature for cocoa is within a range of 8ºC for effective photosynthesis. Against this background, one can conclude, therefore, that the effect of temperature was the within the milieu of cocoa production in the sub-region. This could be the reason for the increasing growth of cocoa in this region than any part of the world. Unlike temperature, the mean data set showed that the regression coefficient of precipitation was positive and significant. The size of the coefficient value of 0.77 was stronger than that of temperature. This indicated that precipitation in the sub-region was contributing immensely to cocoa production. Also, the lag and interaction effects of these climatic variables had a lot of interesting results. For example, while a year lag of precipitation impacted positively on cocoa production, three years lag of temperature impacted negatively on cocoa production in West Africa.

The use of the maximum data set yielded different results in both temperature and precipitation. This sharply indicates that the data set one uses determines the result that could emerge for the analysis. The import inferred here is that this data set mirrors the various extreme events over the historical study period. In line with the assertions of the various scientific reports that temperature would be increasing while precipitation would be decreasing suggested that the sub-region like all other regions of the world should expect such trajectory. This fact makes the maximum data set very important for a study of this nature. The result for temperature indicated a negative regression coefficient of -0.57 and was statistically significant. The size in this result was larger than the previous estimated result when the mean data set was used. This was a clear indication that as temperature increases the more detrimental its impact on cocoa production in the region becomes. In other words, the extreme temperature events recorded denoted a drift away from the expected temperature range for effective cocoa production in the sub-region. Precipitation on the other hand, had a positive significant coefficient of 0.52 but this figure is a reduction when compared to the use of the mean data set result above. What could be gleaned from this result is that falling precipitation reduces its impact on cocoa production in the sub-region.

The lag effects of these climatic variables were also prominent in the analysis of this data set. Several lags were used but it was expedient to focus on the significant ones. A three year lag effect of temperature had a negative coefficient of 0.69. It was statistically significant which suggested that temperature effect on cocoa output lingers up to the third year. One year lag of precipitation had a positive coefficient value of 0.93 which showed that previous year's precipitation substantially promoted cocoa output in the sub-region. The insight drawn from this result of lag effects is an indication that climatic variables do have both instantaneous and lingering effects contemporaneously. It is also worth stating that the lag effects were even larger than the instantaneous effects. The interaction effects of climatic variables and the other leading variables in the model also gave some impressive results. For example labour and capital were significant in cocoa production. More so, their interactions with the climatic variables showed significant support for cocoa production in the region.

The conclusion drawn from the panel study is that the current state of climate change predicated on the two most important variables, their lag effects and their interaction with other leading variables show that both precipitation and temperature are relevant in cocoa production. Their current impacts are not harmful to the cocoa industry. However, because the size of the coefficients increases in the case of temperature and decreases in the case of precipitation with the use of the two data sets is an indication of ominous future for the cocoa industry in West Africa. In other words, given the trajectory of the expected increasing in temperature and declining precipitation, cocoa production is most likely to suffer production declines in the future.

The time series results for the three selected countries offered quite an interesting piece of information in addition to the panel results. While the ECM and the VECM methods resulted in different speed of adjustment for the selected countries, they 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:

- **Nigeria**

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 from 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. This result is akin to that of the panel 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, it would be convenient to state that Nigeria's cocoa industry faces blurred future as well.

The error correction term of the VECM result for Nigeria's case shows low speed of adjustment compared with the ECM result. It reported a coefficient of -0.29 which suggested that only 29% of the previous year's distortions are corrected for in the present year for Nigeria's case when the mean value data set is used. The maximum data set reported was -0.387. This is opposite to the result obtained in the Engle-Granger ECM approach for Nigeria. This result suggests that the preceding year's disequilibrium is corrected at about 39% annually. The intriguing nature of this result is an indication that the method one uses has serious impact on the results that would be generated. The VECM reported only the lag effects of the climatic and the leading variables. The pattern has been very consistent with the use of the two data sets for Nigeria. The mean result showed -0.296 and -0.279 of lag one and lag two for temperature respectively. The maximum data set reported -0.312 and -0.306 of lag one and lag two respectively for temperature. The result from precipitation followed similar trends with 0.408, 0.393 of lag one and two for the mean data set and 0.241, 0.045 for the maximum data set respectively. The conclusion from this aspect of the results is that lag effects peter out with more lag years (with time) in Nigeria's case.

- **Ghana**

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 condition worsens Ghana would have more capacity or mechanism to adjust 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. 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. Concerning the VECM for Ghana, -0.378 and -0.674 were respectively recorded for mean and maximum data sets. The two values are bigger in size compared to Nigeria's case and also larger in the case of the ECM for Ghana. However, the variables follow the same pattern or distribution.

- **Cote D'Ivoire**

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.

The results of the VECM showed the adjustment parameter is the highest among all the three countries studied. What this result means is that about 82% of the previous year's disequilibrium is corrected for in the current year. The lag effects of the variables showed similar

conclusions like those of Ghana and Nigeria.

- ***Objective two: "To simulate the possible future changes in cocoa production due to climate change under various temperature and precipitation scenarios"***

To achieve the second specific objective two sets of simulation experiments were carried out. First, an in-sample simulation was used to track the ability of the model to replicate historical records and for short-run forecasting. Based on its strong predictive power, an out-sample simulation was carried out utilizing plausible scenarios from various scientific reports. The basic scenarios were then used to create various sensitivity combinations of temperature and precipitation on cocoa output. The combinations were six and their results are as follows:

- The first scenario result indicated that decreasing temperature and rising precipitation would lead to an increase in cocoa output. However, the rate of change takes the form of increases, becomes constant and diminishes suggesting that extreme weather condition that would lead to temperature declining with increasing precipitation would only lead to transitory increases in cocoa output which would eventually peter out.
- The second scenario result implied that with constant temperature at the 2009 historical data and with falling precipitation cocoa output would have a continues decline. This suggested that the blend of these climatic variable inputs are very essential. This substantiates the findings of Lawal *et al* (2007), that a combination of optimal temperature, minimal rainfall and relative humidity gives a better yield.
- The third scenario encapsulates a falling trend in both temperature and precipitation. In such a case, cocoa output declines. The description is that, a falling temperature and a falling precipitation do not augur well for cocoa production in the sub-region.
- The fourth scenario examined a constant precipitation and falling temperature which result in increasing cocoa output over the period. However, the rate of change of the output growth was very marginal. What this result means is that pegging precipitation at its 2009 historical data and envisioning a declining temperature will bring about increses in cocoa output. The expected rate of change is woefully inconsequential for the sub-region.
- Scenario five unfolds instances where temperature rises with increasing precipitation. In such instances, cocoa output increases. The anticipated increases are, however, at a diminishing rate. This adverse picxture suggests that increasing temperature in the presence of increasing precipitation could only be viewed as a transitory event for the cocoa industry in West Africa.

- Scenario six is the most plausible trajectory of climate change on cocoa output. In other words, this scenario is the most probable among all the unpleasnt scenarios and this mirrors the current state of the event according to the IPCC (2007), UNDP(2009) and other scientific reports. It foresees a rising temperature and a falling precipitation. The result indicated that cocoa output would fall depending on the actual rate of the falling and rising trajectory of these variables. This result is threating and suggests that cocoa output in the Sub-region faces serious threat in the nearest future if nothing is done to mitigate or adapt to climate change.

The conclusion of the simulation exercise mirrors the results of the maximum dataset. The most plausible trajectory predicts that the cocoa industry faces an ominous future.

CHAPTER SIX

SUMMARY, CONCLUSION AND LESSONS FOR POLICY

This section summarizes the main conclusions of this thesis and lessons have been drawn for policy implementation. The first section summarizes and presents the major findings, and conclusion of the study. Section two draws lessons for policy prescription and the final section discuss the limitations of the thesis and offers suggestions for future research.

6.1. Summary and conclusion

Evidence from literature has shown that cocoa production in West Africa constitutes about 70% of the World market, generates about $2 billion annually and therefore significantly contributes to the economies of these producing countries. It is also very clear that climate change due to anthropogenic factors is warming the earth such that average global temperature has risen by about 0.7°C (1.3°F) leading to changing local rainfall patterns as well as shifting ecological zones, and that the trend is accelerating with Africa labeled as having high vulnerability to climate change because of its heavy dependence on rain fed agriculture and limited coping capacity.

Arising from these facts, the thesis considered eight cocoa producing countries in West Africa to ascertain whether climate change has impact on their output. Major climatic variables, namely temperature and precipitation, capable of influencing cocoa production were considered alongside other leading inputs for the analysis. Both mean and maximum values of these variables were separately considered for the analysis. Two specific objectives were executed to achieve the broader objective of examining the current and future impact of climate change on cocoa production. They were: (i) To determine the extent of impact of climate change on cocoa production in West Africa; and (ii) To Simulate for the possible future changes in cocoa production due to climate change under various temperature and precipitation scenarios.

Consequently, annual data on cocoa output, labour, capital, temperature and precipitation covering 41 years (1969-2009) were sourced and used for the estimation in both panel setting and country time series method in some of the selected countries. Regarding the first objective, the conclusion drawn is as follows:

With the Mean dataset:

i) Cocoa production directly and significantly depends on labour input in West Africa. The implication is that cocoa output in the sub-region could increase if labour input is increased in the cocoa sector. This result is similar to the conclusion of Lundstedt et al, (2009) that cocoa is labour intensive.

ii) Capital input was found not to be significant which implies that cocoa output does not significantly depend on fertilizer input.

iii) Mean temperature values did not show any significant impact on cocoa production in West Africa. The inference here is that cocoa grows well within a particular range of temperature. Beyond the required range temperature input tend to negate cocoa production. This implies the mean values are still within the range for which reason its impact is not felt. This supports the conclusions drawn by Ajewole *et al,* (2010) that there is positive weak correlation between cocoa yield and temperature in Nigeria.

iv) Precipitation positively and significantly supports cocoa production in West Africa. While this result is in line with the findings of Anim-Kwapong et al (2004), it is contrary to the results of Ajewole *et al,* (2010).

v) Precipitation has a negative relationship with labour but their combined interaction significantly affects cocoa production in West Africa. This implies that while precipitation serves as a catalyst to cocoa production, its constant flow and or excesses tend to reduce the effectiveness of labour input in the production of cocoa.

vi) The combined interaction of capital (Fertilizer input) and temperature is negative to cocoa production, suggesting that even in the wake of abundance application of fertilizer cocoa may not grow well if temperature is in excess of what is required. This suggests that the blend of growth input and facilitating inputs are of good support to cocoa production. This corroborates with the findings of Emaku *et al*, (2007), that a combination of optimal temperature, minimal rainfall and relative humidity will give a better yield.

vii) Temperature and precipitation do have lag effects on cocoa production. While a year lag of precipitation impacted positively on cocoa production, three years lag of temperature impacts negatively on cocoa production in West Africa. These facts support Guan's (2006) assertion that, unlike arable crops, tree crops do not have instantaneous effect of climatic fluctuations.

With the maximum values:

i) Both capital and labour significantly contributes positively to cocoa production in West Africa. The implication is that as temperature increases and precipitation falls, more of labour and fertilizer input become very relevant in the production process of cocoa in West Africa.

ii) Unlike the mean values, the maximum values suggest that the two main climatic variables do have substantial impact on cocoa production. While temperature is negatively impacting on cocoa output, precipitation is having a positive effect on cocoa production in West Africa. A careful observation of the results show that the size of the coefficients of these climatic variables change with the data used for the analysis. Specifically, whereas that of temperature increase in size, precipitation reduces. This outcome corroborates with many of the studies done in a localized form within West Africa such as Anim-Kwapong et al, (2004) in Ghana, Oyekale *et al,* (2009) in Nigeria; Nhemachena (2006) in Zimbabwe, as well as Ajewole and Sadiq (2010), Nigeria.

iii) The interaction of labour and precipitation is good for production of cocoa. However, the result suggests that one of them has a reducing effect on the other. At best their blend in their rightful proportions would lead to efficient use in the production process of cocoa.

iv) In the same vein, the interaction of capital (fertilizer) and temperature suggests that extreme temperature does not combine well with fertilizer application. The implication is that fertilizer application during high periods of temperature would reduce the effectiveness of its application thereby negatively impacting on cocoa output.

v) Finally, Lag effects of temperature and precipitation are also apparent in the sub-region as having impact on cocoa production. The result suggests that temperature's negative effect lingers up to a three year lag on cocoa output. Precipitation, however positively impacts on cocoa output up to a year effect. This finding confirms Guan's (2006) assertion.

Concerning the second empirical objective, a simulation in the form of high sensitivity analysis was undertaken to ascertain the future state of the cocoa industry in the wake of climate apprehension. The first scenario indicates that decreasing temperature and rising precipitation will lead to cocoa output increasing. However, the rate of change increases, becomes constant and diminishes suggesting that extreme weather condition that would lead to temperature declining but with increasing precipitation will only lead to transitory increases in cocoa output which will eventually peterout.

The second scenario result implies that with constant temperature at the 2009 historical data, and falling precipitation will lead to declining cocoa output suggesting that the blend of these climatic variable inputs are very essential. This substantiates the findings of Emaku et al, (2007), that a combination of optimal temperature, minimal rainfall and relative humidity will give a better yield.

The third scenario encapsulates a falling trend in both temperature and precipitation which results in declining cocoa output. The description is that a falling temperature and a falling precipitation do not augur well for cocoa production in the sub-region. This outcome agrees to Emaku *et al,* (2007).

The fourth scenario examines contant precipitation and falling temperature which results in increasing cocoa output over the period. However, the rate of change of the output growth is very marginal. What this result means is that pegging precipitation at its 2009 historical data and envisioning a declining temperature will bring about increses in cocoa output. The expected rate of change is unfortunately unappreciative for the Sub-region.

Scenario five unfolds instances where temperature rises with increasing precipitation which results in increases in cocoa output. The anticipated increases are, however, at diminishing rate. This graceless pixture suggests that rising temperature in the presence of increasing precipitation can only be viewed as a transitory event in West Africa.

The final one is the most probable among all the unpleasnt scenarios and mirrors the current state of affairs according to the IPCC (2007), UNDP(2009) and so on. It foresees a rising temperature and a falling precipitation. The result indicates that cocoa output will fall depending on the actual rate of the falling and the rising trajectory of these variables. This result is threating and it suggests that cocoa output in the sub-region faces serious threat in the nearest future if nothing is done to mitigate or adapt to climate change.

To cater for possible omitted variables in the panel estimation, specific country time series analysis was further embarked upon. Three countries, namely, Nigeria, Ghana and Cote D'Ivoire constituting 67% of the World market of cocoa were selected for this exercise. In this time series analysis both the Engle Granger and Johansen Error Correction Methods (ECM & VECM) were used. The conclusions drawn are as follows:

With the ECM Results**:**

(i) The speed of adjustment following previous disequilibrium differs from one country to another.

(ii) The speed of adjustment reduces with the maximum value estimation when compared to the minimum estimation results. This suggests that as climatic factors move towards extreme cases, the less or slower realignment towards equilibrium becomes. Ghana seems to have the capacity to adjust faster than Nigeria and Cote D'Ivoire should climate impact hit the extreme.

(iii) The variables in the parsimonious model exhibited different significant levels, size and signs from one country to the other and more so from using the mean or maximum climatic values. What this suggests is that country differences actually exist in terms of these variables and as such supporting the assertion of Shah *et al*, (2008) that "country specific studies are strongly recommended".

(iv) Finally, the interactive effects of the variables were significant across all the countries studied. This is so for the interaction of capital and temperature on one hand, and labour and precipitation on the other hand.

With the VECM Results:

(i) The VECM results also follow the same pattern as the ECM in terms of the country adjustment speed arising from previous year's distortions.

(ii) Though this estimation was peculiar to the lag effects of the participating variables, it generally agrees with the findings of the ECM in respect of country differences. What can therefore be deduced from the VECM estimation results is that lag effects of climatic variables strongly differ from one country to the other, supporting Shah *et al* (2008) statement that country specific studies are encouraged.

6.2. Lessons for policy

This thesis has shown the various ways through which precipitation and temperature variation can affect cocoa production in West Africa. This research work might be a useful resource material to the agronomist, meteorologist and other related environmental management fields and more importantly policy holders (Governments) of West Africa.

Since the maximum climatic values used for the analysis part of the thesis signifies extreme events that have occurred over the years in West Africa, the severity of which differ from one country to the other suggests that country meteorological forecast is crucial for cocoa farmers. As such, governments giving technical and institutional support and attractive incentive systems to these agencies and individuals involved in making forecast information, especially long term forecast, more accessible to cocoa farmers would go a long way to boost cocoa production in the sub-region. Consequently, establishing some vital institutions like National Drought Early Warning and Monitoring System, as found in some of the advanced countries, in addition to the national weather institutions would be of immense help. The mandate of such institutions could be focused on providing decision makers and other stakeholders at all levels with information from the outset, continuation and termination, and severity of drought conditions and excess rains. Since most farmers are far from such information, country governments in the respective countries could design ways of making such information available to farmers, possibly through agricultural extension officers so as to widen and broaden farmers' knowledge on climate issues.

An important aspect of a combined adaptation and mitigation strategy that would help is to encourage cocoa farmers embark on serious cocoa shade practices that can contribute to buffering temperatures and also improve hydrological cycling. This lofty practice requires policies to encourage tree planting and maintenance of shade on cocoa farms. Shaded cocoa cropping system is a sustainable agricultural land use system that provides relatively high values of environmental services. The ecological and environmental benefits of this system would include habitat conservation, climate change mitigation, and hydrological cycling and watershed protection. This will go a long way to boost cocoa farming and at the same time contribute to efforts geared at global climate change mitigation.

As an adaptation strategy, serious research should be conducted towards developing seeds that can resist adverse effect of weather. This approach has been successful in many ways in the arable crops and the belief is that this is possible under tree crops like cocoa. In the light of this, development institutions aimed at addressing concerns related to weather, could focus on weather resisting variety of cocoa beans, as a matter of urgency. They could also be resourced in the respective countries to research into the possibility of faster yielding variety and not just higher yielding as it is the case now. Again, programmes of developing drought tolerant cocoa planting materials and improved agronomic practices to sustain cocoa production and farmers' livelihood would be ideal.

As indicated by the results of fertilizer application which increases with the level of temperature, cocoa farmers should be trained on the relevance of soil test to know the fertility status of their cocoa farms which will inform them about the quantity of fertilizer that may be required rather than their traditional quantity requirement. The results show that additional fertilizer would be needed in hot weather than the normal weather. As such, the ability of extension officers to make this information available to farmers is imperative.

Linked to the above point is also the need for favorable credit policy and crop insurance for cocoa farmers in the presence of climate change effects. Credit access and crop insurance are two important measures in coping against climate change. Credit will enable farmers to purchase more fertilizer inputs and hire extra labour for application, and crop insurance will serve as a hedge against the uncertain effects of climate change.

Farmers should be sensitized and encouraged to improve their level of education on climate change and its consequences. This is quite essential, in that it could enable them to adopt best practices for adaptation purposes. In line with this, drought management policy through information systems about changing climate conditions and patterns, preparatory practices and options to deal with eventuality of drought must be set in place.

Traditionally, irrigation has not been part of the cocoa farming systems in West Africa; hence, as part of adaptation strategy, policies to promote the establishment of irrigation systems in farms through the provision of infrastructure, education and training will definitely be of immense help to cocoa farmers. But as a word of caution, cocoa farmers are quite conservative and it, therefore, requires a very effective extension and credit systems to assist farmers to accept innovations and adopt the use of new technologies.

Mitigation policy could be to rehabilitate and restore a sustainable production of degraded and moribund cocoa farms, and forestlands previously cultivated to cocoa as part of measures to reduce or stop the rate of migration and deforestation that encourage and exacerbate adverse impact of climate change.

6.3. Limitations of the study and suggestions for future research

Although the translog framework derived in a panel setting, estimated, solved and simulated under various scenarios as well as the time series approach of the ECM and the VECM addresses the objectives of the study, it is not devoid of issues for improvement. Actually, behind the numbers and the rigorous estimations of the impact of climate change on cocoa production is the overwhelming fact that the current generation is running down upon unsustainable ecological debt that future generations will inherit. A holistic way to handle the current menace is by viewing it from the perspective of self-protection and self-insurance. In literature, the former is referred to mitigation and the later termed adaptation. Whatever way the two concepts are viewed from, it still stands out as two general risks strategies associated with climate change.

Implementing such strategies require private or public investment to reduce the severity of any realized net damages to society. This means, a nation or individual would have to shift resources from good to bad states of nature; or by building capacity to deal with gradual and extreme changes. A more realistic way to look at this in Economics is to quantify the expected costs to the expected benefits and then compare the two risk reduction strategies. This will then enable policy makers to decide on the trade-off between mitigation and adaptation.

Incorporating such ideas in a form of extension to this study would do more justice to the reality than this study has attempted to do. In other words, this study has unveiled the fact that climate change is having some level of impact on cocoa production and has further shown how bleak the future is for cocoa production in the Sub-region, but could not estimate the cost of damages and benefits that are involved to enable decision makers to make informed choice on adaptation and mitigation strategies. Such course is expected to build upon this work so that a detailed examination of the impact of climate change in the Sub-region would be realized.

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Appendix A.

Table A1: Results of the Hausman test for Fixed / Random effects.

Variables	Coefficients			
	(b) Fixed	(B) Random	(b-B) difference	Sqrt (diag) (V_b-V_B)). S.E.
LnL	1.180773	2.07522	-.8944474	.0829716
Lnk	0.5802552	1.82427	-1.244015	-
Lnt	-.3019058	-1.333221	1.30303	-
LnP	1.772345	-.4292913	.1982184	-
LnlLnp	-.2310729	-.4292913	.1982184	-
LnkLnt	-.389708	- 2.576147	2.186439	-
Lnt(-3)	1.861819	-1.004671	2.866489	-
Lnp(-1)	-.1436186	0.8680576	-1.011676	-

Note: b = consistent under Ho and Ha; obtained from xtreg, B = inconsistent under Ha, efficient under Ho; obtained from xtreg , Test: Ho: difference in coefficients not systematic, Chi2(8) = (b-B)'[(V_b-V_B)^(-1)](b-B). = -45.21 chi2<0 ==> model fitted on these data fails to meet the asymptotic assumptions of the Hausman test.

Table A 2: Results of Breauch- Pagan Lagrangian Multiplier (LM) Test.(for random effects:)

$$Lny\ [id, t] = Xb + u\ [id] + e\ [id, t]$$

Estimated results:	Var	Sd= sqrt(Var)
Lny	1.855869	1.362303
e	0.0687981	0.2622939
u	0	0

Test: Var (u) = 0 chi2 (1) = 3339.02 Prob > chi2 = 0.0000

Appendix B

Table B1: Continuation of the Simulation Results (From 2021-2050)

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
-8.38764	-9.08661	-9.78558	-10.4846	-11.1835	-11.8825	-12.5815	-13.2804	-13.9794	-14.6784	-15.3773	-16.0763	-16.7753	-17.4743	-18.1732
-4.83506	-5.79405	-6.75304	-7.71202	-8.67101	-9.63	-10.589	-11.548	-12.507	-13.4659	-14.4249	-15.3839	-16.3429	-17.3019	-18.2609
-5.14521	-6.1042	-7.06319	-8.02217	-8.98116	-9.94015	-10.8991	-11.8581	-12.8171	-13.7761	-14.7351	-15.6941	-16.6531	-17.612	-18.571
-5.45536	-6.41435	-7.37334	-8.33232	-9.29131	-10.2503	-11.2093	-12.1683	-13.1273	-14.0862	-15.0452	-16.0042	-16.9632	-17.9222	-18.8812
-5.76551	-6.7245	-7.68348	-8.64247	-9.60146	-10.5604	-11.5194	-12.4784	-13.4374	-14.3964	-15.3554	-16.3144	-17.2734	-18.2323	-19.1913
-7.07294	**-8.03193**	**-8.99092**	**-9.9499**	**-10.9089**	**-11.8679**	**-12.8269**	**-13.7858**	**-14.7448**	**-15.7038**	**-16.6628**	**-17.6218**	**-18.5808**	**-19.5398**	**-20.4988**
-6.38581	-7.3448	-8.30378	-9.26277	-10.2218	-11.1807	-12.1397	-13.0987	-14.0577	-15.0167	-15.9757	-16.9347	-17.8937	-18.8526	-19.8116
-6.69596	-7.65495	-8.61393	-9.57292	-10.5319	-11.4909	-12.4499	-13.4089	-14.3679	-15.3268	-16.2858	-17.2448	-18.2038	-19.1628	-20.1218
-7.00611	-7.9651	-8.92408	-9.88307	-10.8421	-11.801	-12.76	-13.719	-14.678	-15.637	-16.596	-17.555	-18.514	-19.4729	-20.4319
-7.31626	-8.27525	-9.23423	-10.1932	-11.1522	-12.1112	-13.0702	-14.0292	-14.9882	-15.9471	-16.9061	-17.8651	-18.8241	-19.7831	-20.7421
-7.62641	-8.5854	-9.54438	-10.5034	-11.4624	-12.4213	-13.3803	-14.3393	-15.2983	-16.2573	-17.2163	-18.1753	-19.1343	-20.0932	-21.0522
-7.93656	-8.89554	-9.85453	-10.8135	-11.7725	-12.7315	-13.6905	-14.6495	-15.6085	-16.5674	-17.5264	-18.4854	-19.4444	-20.4034	-21.3624
-8.24671	-9.20569	-10.1647	-11.1237	-12.0827	-13.0416	-14.0006	-14.9596	-15.9186	-16.8776	-17.8366	-18.7956	-19.7545	-20.7135	-21.6725
-8.55686	-9.51584	-10.4748	-11.4338	-12.3928	-13.3518	-14.3108	-15.2698	-16.2288	-17.1877	-18.1467	-19.1057	-20.0647	-21.0237	-21.9827
-8.86701	-9.82599	-10.785	-11.744	-12.703	-13.6619	-14.6209	-15.5799	-16.5389	-17.4979	-18.4569	-19.4159	-20.3748	-21.3338	-22.2928
-9.17716	-10.1361	-11.0951	-12.0541	-13.0131	-13.9721	-14.9311	-15.8901	-16.8491	-17.808	-18.767	-19.726	-20.685	-21.644	-22.603
-9.48731	-10.4463	-11.4053	-12.3643	-13.3233	-14.2822	-15.2412	-16.2002	-17.1592	-18.1182	-19.0772	-20.0362	-20.9951	-21.9541	-22.9131
-9.79746	-10.7564	-11.7154	-12.6744	-13.6334	-14.5924	-15.5514	-16.5104	-17.4693	-18.4283	-19.3873	-20.3463	-21.3053	-22.2643	-23.2233
-10.1076	-11.0666	-12.0256	-12.9846	-13.9436	-14.9025	-15.8615	-16.8205	-17.7795	-18.7385	-19.6975	-20.6565	-21.6154	-22.5744	-23.5334
-10.4178	-11.3767	-12.3357	-13.2947	-14.2537	-15.2127	-16.1717	-17.1307	-18.0896	-19.0486	-20.0076	-20.9666	-21.9256	-22.8846	-23.8436
-10.7279	-11.6869	-12.6459	-13.6049	-14.5639	-15.5228	-16.4818	-17.4408	-18.3998	-19.3588	-20.3178	-21.2768	-22.2357	-23.1947	-24.1537
-11.0381	-11.997	-12.956	-13.915	-14.874	-15.833	-16.792	-17.751	-18.7099	-19.6689	-20.6279	-21.5869	-22.5459	-23.5049	-24.4639
-11.3482	-12.3072	-13.2662	-14.2252	-15.1842	-16.1431	-17.1021	-18.0611	-19.0201	-19.9791	-20.9381	-21.8971	-22.856	-23.815	-24.774
-11.6584	-12.6173	-13.5763	-14.5353	-15.4943	-16.4533	-17.4123	-18.3713	-19.3302	-20.2892	-21.2482	-22.2072	-23.1662	-24.1252	-25.0842
-11.9685	-12.9275	-13.8865	-14.8455	-15.8044	-16.7634	-17.7224	-18.6814	-19.6404	-20.5994	-21.5584	-22.5174	-23.4763	-24.4353	-25.3943
-12.2787	-13.2376	-14.1966	-15.1556	-16.1146	-17.0736	-18.0326	-18.9916	-19.9505	-20.9095	-21.8685	-22.8275	-23.7865	-24.7455	-25.7045
-12.5888	-13.5478	-14.5068	-15.4658	-16.4247	-17.3837	-18.3427	-19.3017	-20.2607	-21.2197	-22.1787	-23.1377	-24.0966	-25.0556	-26.0146
-12.899	-13.8579	-14.8169	-15.7759	-16.7349	-17.6939	-18.6529	-19.6119	-20.5708	-21.5298	-22.4888	-23.4478	-24.4068	-25.3658	-26.3248
-13.2091	-14.1681	-15.1271	-16.0861	-17.045	-18.004	-18.963	-19.922	-20.881	-21.84	-22.799	-23.758	-24.7169	-25.6759	-26.6349
-13.5192	-14.4782	-15.4372	-16.3962	-17.3552	-18.3142	-19.2732	-20.2322	-21.1911	-22.1501	-23.1091	-24.0681	-25.0271	-25.9861	-26.9451
-13.8294	-14.7884	-15.7474	-16.7064	-17.6653	-18.6243	-19.5833	-20.5423	-21.5013	-22.4603	-23.4193	-24.3783	-25.3372	-26.2962	-27.2552
-14.1395	-15.0985	-16.0575	-17.0165	-17.9755	-18.9345	-19.8935	-20.8525	-21.8114	-22.7704	-23.7294	-24.6884	-25.6474	-26.6064	-27.5654
-14.4497	-15.4087	-16.3677	-17.3267	-18.2856	-19.2446	-20.2036	-21.1626	-22.1216	-23.0806	-24.0396	-24.9986	-25.9575	-26.9165	-27.8755
-14.7598	-15.7188	-16.6778	-17.6368	-18.5958	-19.5548	-20.5138	-21.4728	-22.4317	-23.3907	-24.3497	-25.3087	-26.2677	-27.2267	-28.1857
-15.07	-16.029	-16.988	-17.947	-18.9059	-19.8649	-20.8239	-21.7829	-22.7419	-23.7009	-24.6599	-25.6189	-26.5778	-27.5368	-28.4958
-15.3801	-16.3391	-17.2981	-18.2571	-19.2161	-20.1751	-21.1341	-22.0931	-23.052	-24.011	-24.97	-25.929	-26.888	-27.847	-28.806
-15.6903	-16.6493	-17.6083	-18.5673	-19.5262	-20.4852	-21.4442	-22.4032	-23.3622	-24.3212	-25.2802	-26.2392	-27.1981	-28.1571	-29.1161
-16.0004	-16.9594	-17.9184	-18.8774	-19.8364	-20.7954	-21.7544	-22.7134	-23.6723	-24.6313	-25.5903	-26.5493	-27.5083	-28.4673	-29.4263
-16.3106	-17.2696	-18.2286	-19.1876	-20.1465	-21.1055	-22.0645	-23.0235	-23.9825	-24.9415	-25.9005	-26.8595	-27.8184	-28.7774	-29.7364
-16.6207	-17.5797	-18.5387	-19.4977	-20.4567	-21.4157	-22.3747	-23.3337	-24.2926	-25.2516	-26.2106	-27.1696	-28.1286	-29.0876	-30.0466
-16.9309	-17.8899	-18.8489	-19.8079	-20.7668	-21.7258	-22.6848	-23.6438	-24.6028	-25.5618	-26.5208	-27.4797	-28.4387	-29.3977	-30.3567
-17.241	-18.2	-19.159	-20.118	-21.077	-22.036	-22.995	-23.954	-24.9129	-25.8719	-26.8309	-27.7899	-28.7489	-29.7079	-30.6669
-17.5512	-18.5102	-19.4692	-20.4282	-21.3871	-22.3461	-23.3051	-24.2641	-25.2231	-26.1821	-27.1411	-28.1	-29.059	-30.018	-30.977
-17.8613	-18.8203	-19.7793	-20.7383	-21.6973	-22.6563	-23.6153	-24.5743	-25.5332	-26.4922	-27.4512	-28.4102	-29.3692	-30.3282	-31.2872
-18.1715	-19.1305	-20.0895	-21.0485	-22.0074	-22.9664	-23.9254	-24.8844	-25.8434	-26.8024	-27.7614	-28.7203	-29.6793	-30.6383	-31.5973
-18.4816	-19.4406	-20.3996	-21.3586	-22.3176	-23.2766	-24.2356	-25.1946	-26.1535	-27.1125	-28.0715	-29.0305	-29.9895	-30.9485	-31.9075
-18.7918	-19.7508	-20.7098	-21.6688	-22.6277	-23.5867	-24.5457	-25.5047	-26.4637	-27.4227	-28.3817	-29.3406	-30.2996	-31.2586	-32.2176

2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
-18.8722	-19.5712	-20.2701	-20.9691	-21.6681	-22.367	-23.066	-23.765	-24.464	-25.1629	-25.8619	-26.5609	-27.2598	-27.9588	-28.6578
-19.2199	-20.1789	-21.1378	-22.0968	-23.0558	-24.0148	-24.9738	-25.9328	-26.8918	-27.8507	-28.8097	-29.7687	-30.7277	-31.6867	-32.6457
-19.53	-20.489	-21.448	-22.407	-23.366	-24.3249	-25.2839	-26.2429	-27.2019	-28.1609	-29.1199	-30.0789	-31.0379	-31.9968	-32.9558
-19.8402	-20.7992	-21.7581	-22.7171	-23.6761	-24.6351	-25.5941	-26.5531	-27.5121	-28.471	-29.43	-30.389	-31.348	-32.307	-33.266
-20.1503	-21.1093	-22.0683	-23.0273	-23.9863	-24.9452	-25.9042	-26.8632	-27.8222	-28.7812	-29.7402	-30.6992	-31.6582	-32.6171	-33.5761
-21.4577	**-22.4167**	**-23.3757**	**-24.3347**	**-25.2937**	**-26.2527**	**-27.2117**	**-28.1707**	**-29.1296**	**-30.0886**	**-31.0476**	**-32.0066**	**-32.9656**	**-33.9246**	**-34.8836**
-20.7706	-21.7296	-22.6886	-23.6476	-24.6066	-25.5655	-26.5245	-27.4835	-28.4425	-29.4015	-30.3605	-31.3195	-32.2785	-33.2374	-34.1964
-21.0808	-22.0397	-22.9987	-23.9577	-24.9167	-25.8757	-26.8347	-27.7937	-28.7527	-29.7116	-30.6706	-31.6296	-32.5886	-33.5476	-34.5066
-21.3909	-22.3499	-23.3089	-24.2679	-25.2269	-26.1858	-27.1448	-28.1038	-29.0628	-30.0218	-30.9808	-31.9398	-32.8988	-33.8577	-34.8167
-21.7011	-22.66	-23.619	-24.578	-25.537	-26.496	-27.455	-28.414	-29.373	-30.3319	-31.2909	-32.2499	-33.2089	-34.1679	-35.1269
-22.0112	-22.9702	-23.9292	-24.8882	-25.8472	-26.8061	-27.7651	-28.7241	-29.6831	-30.6421	-31.6011	-32.5601	-33.5191	-34.478	-35.437
-22.3214	-23.2803	-24.2393	-25.1983	-26.1573	-27.1163	-28.0753	-29.0343	-29.9933	-30.9522	-31.9112	-32.8702	-33.8292	-34.7882	-35.7472
-22.6315	-23.5905	-24.5495	-25.5085	-26.4675	-27.4264	-28.3854	-29.3444	-30.3034	-31.2624	-32.2214	-33.1804	-34.1394	-35.0983	-36.0573
-22.9417	-23.9006	-24.8596	-25.8186	-26.7776	-27.7366	-28.6956	-29.6546	-30.6136	-31.5725	-32.5315	-33.4905	-34.4495	-35.4085	-36.3675
-23.2518	-24.2108	-25.1698	-26.1288	-27.0878	-28.0467	-29.0057	-29.9647	-30.9237	-31.8827	-32.8417	-33.8007	-34.7597	-35.7186	-36.6776
-23.562	-24.5209	-25.4799	-26.4389	-27.3979	-28.3569	-29.3159	-30.2749	-31.2339	-32.1928	-33.1518	-34.1108	-35.0698	-36.0288	-36.9878
-23.8721	-24.8311	-25.7901	-26.7491	-27.7081	-28.667	-29.626	-30.585	-31.544	-32.503	-33.462	-34.421	-35.38	-36.3389	-37.2979
-24.1823	-25.1412	-26.1002	-27.0592	-28.0182	-28.9772	-29.9362	-30.8952	-31.8542	-32.8131	-33.7721	-34.7311	-35.6901	-36.6491	-37.6081
-24.4924	-25.4514	-26.4104	-27.3694	-28.3284	-29.2873	-30.2463	-31.2053	-32.1643	-33.1233	-34.0823	-35.0413	-36.0002	-36.9592	-37.9182
-24.8026	-25.7615	-26.7205	-27.6795	-28.6385	-29.5975	-30.5565	-31.5155	-32.4745	-33.4334	-34.3924	-35.3514	-36.3104	-37.2694	-38.2284
-25.1127	-26.0717	-27.0307	-27.9897	-28.9487	-29.9076	-30.8666	-31.8256	-32.7846	-33.7436	-34.7026	-35.6616	-36.6205	-37.5795	-38.5385
-25.4229	-26.3818	-27.3408	-28.2998	-29.2588	-30.2178	-31.1768	-32.1358	-33.0948	-34.0537	-35.0127	-35.9717	-36.9307	-37.8897	-38.8487
-25.733	-26.692	-27.651	-28.61	-29.569	-30.5279	-31.4869	-32.4459	-33.4049	-34.3639	-35.3229	-36.2819	-37.2408	-38.1998	-39.1588
-26.0432	-27.0021	-27.9611	-28.9201	-29.8791	-30.8381	-31.7971	-32.7561	-33.715	-34.674	-35.633	-36.592	-37.551	-38.51	-39.469
-26.3533	-27.3123	-28.2713	-29.2303	-30.1893	-31.1482	-32.1072	-33.0662	-34.0252	-34.9842	-35.9432	-36.9022	-37.8611	-38.8201	-39.7791
-26.6635	-27.6224	-28.5814	-29.5404	-30.4994	-31.4584	-32.4174	-33.3764	-34.3353	-35.2943	-36.2533	-37.2123	-38.1713	-39.1303	-40.0893
-26.9736	-27.9326	-28.8916	-29.8506	-30.8096	-31.7685	-32.7275	-33.6865	-34.6455	-35.6045	-36.5635	-37.5225	-38.4814	-39.4404	-40.3994
-27.2838	-28.2427	-29.2017	-30.1607	-31.1197	-32.0787	-33.0377	-33.9967	-34.9556	-35.9146	-36.8736	-37.8326	-38.7916	-39.7506	-40.7096
-27.5939	-28.5529	-29.5119	-30.4709	-31.4299	-32.3888	-33.3478	-34.3068	-35.2658	-36.2248	-37.1838	-38.1428	-39.1017	-40.0607	-41.0197
-27.9041	-28.863	-29.822	-30.781	-31.74	-32.699	-33.658	-34.617	-35.5759	-36.5349	-37.4939	-38.4529	-39.4119	-40.3709	-41.3299
-28.2142	-29.1732	-30.1322	-31.0912	-32.0501	-33.0091	-33.9681	-34.9271	-35.8861	-36.8451	-37.8041	-38.7631	-39.722	-40.681	-41.64
-28.5244	-29.4833	-30.4423	-31.4013	-32.3603	-33.3193	-34.2783	-35.2373	-36.1962	-37.1552	-38.1142	-39.0732	-40.0322	-40.9912	-41.9502
-28.8345	-29.7935	-30.7525	-31.7115	-32.6704	-33.6294	-34.5884	-35.5474	-36.5064	-37.4654	-38.4244	-39.3834	-40.3423	-41.3013	-42.2603
-29.1447	-30.1036	-31.0626	-32.0216	-32.9806	-33.9396	-34.8986	-35.8576	-36.8165	-37.7755	-38.7345	-39.6935	-40.6525	-41.6115	-42.5705
-29.4548	-30.4138	-31.3728	-32.3318	-33.2907	-34.2497	-35.2087	-36.1677	-37.1267	-38.0857	-39.0447	-40.0037	-40.9626	-41.9216	-42.8806
-29.7649	-30.7239	-31.6829	-32.6419	-33.6009	-34.5599	-35.5189	-36.4779	-37.4368	-38.3958	-39.3548	-40.3138	-41.2728	-42.2318	-43.1908
-30.0751	-31.0341	-31.9931	-32.9521	-33.911	-34.87	-35.829	-36.788	-37.747	-38.706	-39.665	-40.624	-41.5829	-42.5419	-43.5009
-30.3852	-31.3442	-32.3032	-33.2622	-34.2212	-35.1802	-36.1392	-37.0982	-38.0571	-39.0161	-39.9751	-40.9341	-41.8931	-42.8521	-43.8111
-30.6954	-31.6544	-32.6134	-33.5724	-34.5313	-35.4903	-36.4493	-37.4083	-38.3673	-39.3263	-40.2853	-41.2443	-42.2032	-43.1622	-44.1212
-31.0055	-31.9645	-32.9235	-33.8825	-34.8415	-35.8005	-36.7595	-37.7185	-38.6774	-39.6364	-40.5954	-41.5544	-42.5134	-43.4724	-44.4314
-31.3157	-32.2747	-33.2337	-34.1927	-35.1516	-36.1106	-37.0696	-38.0286	-38.9876	-39.9466	-40.9056	-41.8646	-42.8235	-43.7825	-44.7415
-31.6258	-32.5848	-33.5438	-34.5028	-35.4618	-36.4208	-37.3798	-38.3388	-39.2977	-40.2567	-41.2157	-42.1747	-43.1337	-44.0927	-45.0517
-31.936	-32.895	-33.854	-34.813	-35.7719	-36.7309	-37.6899	-38.6489	-39.6079	-40.5669	-41.5259	-42.4849	-43.4438	-44.4028	-45.3618
-32.2461	-33.2051	-34.1641	-35.1231	-36.0821	-37.0411	-38.0001	-38.9591	-39.918	-40.877	-41.836	-42.795	-43.754	-44.713	-45.672
-32.5563	-33.5153	-34.4743	-35.4333	-36.3922	-37.3512	-38.3102	-39.2692	-40.2282	-41.1872	-42.1462	-43.1052	-44.0641	-45.0231	-45.9821
-32.8664	-33.8254	-34.7844	-35.7434	-36.7024	-37.6614	-38.6204	-39.5794	-40.5383	-41.4973	-42.4563	-43.4153	-44.3743	-45.3333	-46.2923
-33.1766	-34.1356	-35.0946	-36.0536	-37.0125	-37.9715	-38.9305	-39.8895	-40.8485	-41.8075	-42.7665	-43.7254	-44.6844	-45.6434	-46.6024

Appendix C

Results of Unit Root Tests

Table C1 [13]: Results of Unit Root Tests for Ghana Mean Dataset

Variable		Augmented Dickey-Fuller Test Statistic	Phillips-Perron (PP) Statistic	Conclusion
LNY	Levels	-3.605593 ,(0.8647)	-0.576012,(0.5680)	I(1)
	First Diff	-5.806375**,(0.000)	-5.806375**, (0.0000)	
LNL	Levels	-0.918497, (0.3648)	-2.409311, (0.2090)	I(1)
	First Diff	-3.6155**(0.0001)	-5.0292** (0.0002)	
LNK	Levels	-1.05967, (0.2968)	-2.5875, (0.1612)	I(1)
	First Diff	-2.40200**,(0.0219)	-13.865**,(0.000)	
LNT	Levels	-3.102345, (0.3600)	-3.212342, (0.06320)	I(1)
	First Diff	-7.472408**, (0.0001)	-10.32700**, (0.0032)	
LNP	Levels	-2.034462, (0.3044)	-5.034436, (0.103110)	I(1)
	First Diff	-7.975628**, (0.0000)	-9.994372**, (0.0072)	
LNTYR3	Levels	-0.708077, (0.4859)	-1.726522, (0.924)	I(1)
	First Diff	-3.537337**, (0.0019)	-12.71801**, (0.000)	
LNLLNP	Levels	-0.297017, (0.7686)	-0.745175, (0.4608)	I(1)
	First Diff	-3.348446**, (0.0023)	-14.39087**, (0.0100)	
LNKLNT	Levels	-1.059675, (0.2968)	-2.587501, (0.1612)	I(1)
	First Diff	-13.86552**, (0.000)	-13.86552**, (0.000)	
LNPYR1	Levels	-1.627746, (0.2812)	-1.366480, (0.5887)	I(1)
	First Diff	-6.277467**, (0.0000)	-7.141443**, (0.000)	

Note: **represents variables are significant at the 1 percent level and * at 5% level.

Source: Author's Estimations.

Table C2 [14]: Results of Unit Root Tests for Ghana Maximum Dataset

Variable		Augmented Dickey-Fuller Test Statistic	Phillips-Perron (PP) Statistic	Conclusion
LNY	Levels	-3.605593 ,(0.8647)	-0.576012,(0.5680)	
	First Diff	-5.806375**,(0.000)	-5.806375**, (0.000)	I(1)
LNL	Levels	-0.918497, (0.3648)	-2.409311, (0.2090)	
	First Diff	-3.6155**(0.0001)	-5.0292** (0.0002)	I(1)
LNK	Levels	-1.05967, (0.2968)	-2.5875, (0.1612)	
	First Diff	-3.6155**(0.0001)	-5.0292** (0.0002)	I(1)
LNT	Levels	-1.292394, (0.3044)	-2.65682, (0.30200)	
	First Diff	-7.47240**(0.0000)	-10.32700**(0.0006)	I(1)
LNP	Levels	-1.0000, (0.3287)	-1.73770,(0.0905)	
	First Diff	-4.22278**,(0.0004)	-5.9763**,(0.0001)	I(1)
LNTYR3	Levels	-1.1496,(0.3080)	-1.1496, (0.2060)	
	First Diff	-3.1298**,(0.0032)	-3.14363**,(0.0032)	I(1)
LNLLNP	Levels	-1.3241, (0.3281)	-0.5352, (0.3274)	

	First Diff	-4.22950**,(0.004)	-**(0.0000)	I(1)
LNKLNT	Levels	-0.91897, (0.7714)	-2.318354, (0.1714)	
	First Diff	-13.81690**,(0.000)	-13.43570**,(0.001)	I(1)
LNPYR1	Levels	-1.3221, (0.2004)	-3.60559, (0.9991)	
	First Diff	-5.9054**,(0.000)	-3.135497**,(0.0138)	I(1)

Note: **represents variables are significant at the 1 percent level and * at 5% level.

Source: Author's Estimations.

Table C3 [15]: Results of Unit Root Tests for Cote D'Ivoire Maximum Dataset

Variable		Augmented Dickey-Fuller Test Statistic	Phillips-Perron (PP) Statistic	Conclusion
LNY	Levels	-1.553370, (0.4967)	-1.553370, (0.4967)	
	First Diff	-2.02947**,(0.0496)	-2.0294**, (0.0496)	I(1)
LNL	Levels	-1.51323, (0.2556)	-1.38070., (0.1077)	
	First Diff	-3.32388**(0.0021)	-5.10063** (0.0000)	I(1)
LNK	Levels	-1.394741, (0.5750)	-1.098959, (0.3032)	
	First Diff	-12.45562**,(0.000)	-12.5544**,(0.000)	I(1)
LNT	Levels	-1.256642, (0.3044)	-1.21342, (0.3020)	
	First Diff	-3.15721**(0.0303)	-3.10234**(0.0000)	I(1)
LNP	Levels	-1.980482, (0.2939)	-6.25738,(0.5000)	
	First Diff	-6.100517**,(0.000)	-7.44908**,(0.0001)	I(1)
LNTYR3	Levels	-1.11617,(0.3080)	-1.2210, (0.2060)	
	First Diff	-3.1298**,(0.0330)	-7.2419**,(0.0000)	I(1)
LNLLNP	Levels	-2.73986, (0.70263)	-2.66954, (0.0882)	
	First Diff	-8.156404**,(0.000)	-8.2288**(0.0000)	I(1)
LNKLNT	Levels	-1.328408, (0.6067)	-1.2313, (0.1714)	
	First Diff	-12.53261**,(0.000)	-3.03166**,(0.0404)	I(1)
LNPYR1	Levels	-1.72312, (0.2004)	-1.0853, (0.9991)	
	First Diff	-8.257371**,(0.000)	-8.0319**,(0.0002)	I(1)

Note: **represents variables are significant at the 1 percent level and * at 5% level.

Table C4 [16]: Results of Unit Root Tests for Cote D'Ivoire Maximum Dataset.

Variable		Augmented Dickey-Fuller Test Statistic	Phillips-Perron (PP) Statistic	Conclusion
LNY	Levels	-1.553370, (0.4967)	-1.553370, (0.4967)	
	First Diff	-2.02947**,(0.0496)	-2.0294**, (0.0496)	I(1)
LNL	Levels	-1.51323, (0.2556)	-1.38070., (0.1077)	
	First Diff	-3.32388**(0.0021)	-5.10063** (0.0000)	I(1)
LNK	Levels	-1.394741, (0.5750)	-1.098959, (0.3032)	
	First Diff	-12.45562**,(0.000)	-12.5544**,(0.000)	I(1)
LNT	Levels	-1.149653, (0.3044)	-1.2210, (0.3020)	
	First Diff	-3.1023**(0.0308)	-3.10234**(0.0260)	I(1)
LNP	Levels	-0.51322, (0.1000)	-3.60559,(0.5000)	
	First Diff	-5.0344**,(0.0002)	-11.9763**,(0.0001)	I(1)

LNTYR3	Levels	-1.23855,(0.3080)	-1.30553, (0.3060)	
	First Diff	-3.60558**,(0.0032)	-9.82220**,(0.0000)	I(1)
LNLLNP	Levels	-0.390358, (0.9012)	-0.233131, (0.9714)	
	First Diff	-2.7737**,(0.0410)	-7.931885**(0.0000)	I(1)
LNKLNT	Levels	-0.918497, (0.7714)	-2.318354, (0.1714)	
	First Diff	-13.8169**,(0.000)	-13.43570**,(0.0000)	I(1)
LNPYR1	Levels	-1.61133, (0.28120)	-1.366840, (0.5887)	
	First Diff	-6.27746**,(0.000)	-14.96304**,(0.0000)	I(1)

Note: **represents variables are significant at the 1 percent level and * at 5% level.

Source: Author's Estimation Results, 2011.

Results of Cointegration Tests

Table C5 [20]: Result of the Multivariate Johansen Cointegration Test for Ghana (Mean Values) based on Trace Statistic & Maximum Eigen Values.

Hypothesized No. of CE(s)				Critical Values	
Null	Alternative	Eigen Value	Trace Statistic	5%	1%
$r = 0$	$r = 1$ **	0.661697	83.81016	68.52	76.07
$r \leq 1$	$r = 2$	0.458454	41.54143	47.21	54.46
$r \leq 2$	$r = 3$	0.277876	17.62169	29.68	35.65
$r \leq 3$	$r = 4$	0.116219	4.924928	15.41	20.04
$r \leq 4$	$r = 5$	0.002731	0.106651	3.76	6.65
Notes: -Trace statistic indicates 1 cointegrating equation(s) at both 5% and 1% level. *(**) denotes rejection of the hypothesis at 5 %(1%) levels.					
Null	Alternative	Eigen Value	Max Eigen Value	Critical Values	
				5%	1%
$r = 0$	$r = 1$ **	0.661697	42.26873	33.46	38.77
$r \leq 1$	$r = 2$	0.458454	23.91975	27.07	32.24
$r \leq 2$	$r = 3$	0.277876	12.69676	20.97	25.52
$r \leq 3$	$r = 4$	0.116219	4.818277	14.07	18.63
$r \leq 4$	$r = 5$	0.002731	0.106651	3.76	6.65
Notes: Maximum Eigen Value test indicates 1 cointegrating equation(s) at both 5% and 1% level. *(**) denotes rejection of the hypothesis at 5 %(1%) level.					

Source: Author's Estimation Results, 2011.

Table C6 [21]: Result of the Multivariate Johansen Cointegration Test for Ghana (Maximum Values) based on Trace Statistic & Maximum Eigen Values.

Hypothesized No. of CE(s)				Critical Values	
Null	Alternative	Eigen Value	Trace Statistic	5%	1%
$r = 0$	$r = 1$ *	0.697711	69.93471	68.52	76.07
$r \leq 1$	$r = 2$	0.221500	23.27622	47.21	54.46
$r \leq 2$	$r = 3$	0.162054	13.51116	29.68	35.65
$r \leq 3$	$r = 4$	0.121637	6.615916	15.41	20.04

$r \leq 4$	$r = 5$	0.039158	1.557798	3.76	6.65
Notes: -Trace statistic indicates 1 cointegrating equation(s) at the 5% level. Trace test indicates no cointegrating equation at 1% level. *(**) denotes rejection of the hypothesis at 5 %(1%) levels.					
Null	Alternative	Eigen Value	Max Eigen Value	Critical Values	
				5%	1%
$r = 0$	$r = 1$**	0.697711	46.65849	33.46	38.77
$r \leq 1$	$r = 2$	0.221500	9.765062	27.07	32.24
$r \leq 2$	$r = 3$	0.162054	6.895241	20.97	25.52
$r \leq 3$	$r = 4$	0.121637	5.058118	14.07	18.63
$r \leq 4$	$r = 5$	0.039158	1.557798	3.76	6.65
Notes: Maximum Eigen Value test indicates 1 cointegrating equation(s) at both 5% level and 1% level. *(**) denotes rejection of the hypothesis at 5 %(1%) level.					

Source: Author's Estimation Results, 2011.

Table C7 [22]: Result of the Multivariate Johansen Cointegration Test for Cote D'Ivoire (Mean Values) based on Trace Statistic & Maximum Eigen Values.

Hypothesized No. of CE(s)				Critical Values	
Null	Alternative	Eigen Value	Trace Statistic	5%	1%
$r = 0$	$r = 1$**	0.644155	80.37471	68.52	76.07
$r \leq 1$	$r = 2$	0.388486	40.07762	47.21	54.46
$r \leq 2$	$r = 3$	0.260173	20.89677	29.68	35.65
$r \leq 3$	$r = 4$	0.195763	9.144534	15.41	20.04
$r \leq 4$	$r = 5$	0.016476	0.647923	3.76	6.65
Notes: -Trace statistic indicates 1 cointegrating equation(s) at both 5% and 1% level. *(**) denotes rejection of the hypothesis at 5 %(1%) levels.					
Null	Alternative	Eigen Value	Max Eigen Value	Critical Values	
				5%	1%
$r = 0$	$r = 1$**	0.644155	40.29709	33.46	38.77
$r \leq 1$	$r = 2$	0.388486	19.18086	27.07	32.24
$r \leq 2$	$r = 3$	0.260173	11.75223	20.97	18.63
$r \leq 3$	$r = 4$	0.195763	8.496611	14.07	6.65
$r \leq 4$	$r = 5$	0.016476	0.647923	3.76	-
Notes: Maximum Eigen Value test indicates 1 cointegrating equation(s) at both 5% and 1% level. *(**) denotes rejection of the hypothesis at 5 %(1%) level.					

Source: Author's Estimation Results, 2011.

Table C8 [23]: Result of the Multivariate Johansen Cointegration Test for Cote D'Ivoire (Maximum Values) based on Trace Statistic & Maximum Eigen Values.

Hypothesized No. of CE(s)				Critical Values	
Null	Alternative	Eigen Value	Trace Statistic	5%	1%
$r = 0$	$r = 1$ **	0.660945	83.66419	68.52	76.07
$r \leq 1$	$r = 2$	0.458271	41.48204	47.21	54.46
$r \leq 2$	$r = 3$	0.277218	17.57545	29.68	35.65
$r \leq 3$	$r = 4$	0.116361	4.914214	15.41	20.04
$r \leq 4$	$r = 5$	0.0022296	0.089653	3.76	6.65
Notes: -Trace statistic indicates 1 cointegrating equation(s) at both 5% and 1% level. *(**) denotes rejection of the hypothesis at 5 %(1%) levels.					
Null	Alternative	Eigen Value	Max Eigen Value	Critical Values	
				5%	1%
$r = 0$	$r = 1$ **	0.660945	42.18216	33..46	38.77
$r \leq 1$	$r = 2$	0.458271	23.90658	27.07	32.24
$r \leq 2$	$r = 3$	0.277218	12.661224	20.97	25.52
$r \leq 3$	$r = 4$	0.116361	4.824561	14.07	18.63
$r \leq 4$	$r = 5$	0.0022296	0.089653	3.76	6.65
Notes: Maximum Eigen Value test indicates 1 cointegrating equation(s) at both 5% and 1% level. *(**) denotes rejection of the hypothesis at 5 %(1%) levels.					

Source: Author's Estimation Results, 2011.

Appendix D

Over-parameterized Model for the selected Countries.

Table D 1: The variables for the Over-parameterized Engle-Granger's ECM estimation.

d(lny) d(lnl) d(lnk) d(lnt) d(lnp) d(lntyr3) d(lnllnp) d(lnklnt) d(lnpyr1) d(lny(-1)) d(lny(-2))
d(lnl(-1)) d(lnl(-2)) d(lnk(-1)) d(lnk(-2)) d(lnt(-1)) d(lnt(-2)) d(lnp(-1)) d(lnp(-2)) d(lntyr3(-1))
d(lntyr3(-2)) d(lnllnp(-1)) d(lnllnp(-2)) d(lnklnt(-1)) d(lnklnt(-2)) d(lnpyr1(-1)) d(lnpyr1(-2)) ecm(-1)

Source: Author's Estimation Results, 2011.

Table D 2: Mean climatic Values for Nigeria

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNL)	0.310934	1.036232	0.300062	0.7697
D(LNK)	-0.019492	0.045851	-0.425111	0.6790
D(LNT)	-72.15466	107.2978	-0.672471	0.5152
D(LNP)	103.8618	156.9230	0.661865	0.5217
D(LNTYR3)	0.020512	0.083999	0.244200	0.8116
D(LNLLNP)	0.764163	0.536989	1.423050	0.1825
D(LNKLNT)	-0.410006	1.484190	-0.276249	0.7875
D(LNPYR1)	0.489659	0.524439	0.933681	0.3705
D(LNY(-1))	0.312188	0.310321	1.006014	0.3360
D(LNY(-2))	-0.099199	0.346315	-0.286441	0.7799
D(LNL(-1))	0.975507	1.534668	0.635647	0.5380
D(LNL(-2))	0.909202	1.289721	0.704960	0.4955
D(LNK(-1))	0.022409	0.057511	0.389642	0.7042
D(LNK(-2))	0.046631	0.044767	1.041645	0.3199
D(LNT(-1))	13.61085	58.40137	0.233057	0.8200
D(LNT(-2))	33.29357	61.81434	0.538606	0.6009
D(LNP(-1))	-24.29352	87.20233	-0.278588	0.7857
D(LNP(-2))	-53.00101	90.96882	-0.582628	0.5719
D(LNTYR3(-1))	-0.013325	0.081726	-0.163043	0.8734
D(LNTYR3(-2))	-0.022072	0.097885	-0.225489	0.8257
D(LNLLNP(-1))	0.090487	0.426279	0.212273	0.8358
D(LNLLNP(-2))	-1.124584	1.018852	-1.103775	0.2933
D(LNKLNT(-1))	-1.404507	2.205470	-0.636829	0.5373
D(LNKLNT(-2))	-1.315506	1.845875	-0.712673	0.4909
D(LNPYR1(-1))	-0.189178	0.153285	-1.234160	0.2429
D(LNPYR1(-2))	0.163832	0.166238	0.985530	0.3455
ECM(-1)	-0.375142	0.296528	-1.265114	0.2320
R-squared	0.568328	Mean dependent var		0.006221
Adjusted R-squared	-0.451987	S.D. dependent var		0.077648
S.E. of regression	0.093564	Akaike info criterion		-1.718970
Sum squared resid	0.096297	Schwarz criterion		-0.555422
Log likelihood	59.66043	Durbin-Watson stat		1.758789

Table D 3: Maximum climatic Values for Nigeria

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNL)	-0.669026	10.61163	-0.439992	0.6685
D(LNK)	-0.469394	2.115644	-0.221868	0.8285
D(LNT)	43.24549	125.3384	0.345030	0.7366
D(LNP)	-0.006323	0.043834	-0.144244	0.8879
D(LNTYR3)	-0.747430	84.99920	-0.349973	0.7330
D(LNLLNP)	-0.960191	9.727076	-0.407131	0.6917
D(LNKLNT)	0.340401	1.477072	0.230456	0.8220
D(LNPYR1)	0.008085	0.032306	0.250274	0.8070
D(LNY(-1))	0.320638	0.360085	0.890450	0.3923
D(LNY(-2))	-0.056876	0.435399	-0.130629	0.8984
D(LNL(-1))	-0.483489	1.928402	-0.250720	0.8067
D(LNL(-2))	-0.177507	0.515295	-0.344477	0.7370
D(LNK(-1))	0.582255	2.625083	0.221804	0.8285
D(LNK(-2))	-1.002647	2.106436	-0.475992	0.6434
D(LNT(-1))	-106.3797	128.5604	-0.827469	0.4256
D(LNT(-2))	-18.55457	171.3110	-0.108309	0.9157
D(LNP(-1))	-0.034605	0.049161	-0.703911	0.4961
D(LNP(-2))	0.039475	0.064380	0.613156	0.5522
D(LNTYR3(-1))	74.08422	87.00929	0.851452	0.4127
D(LNTYR3(-2))	10.66012	117.0273	0.091091	0.9291
D(LNLLNP(-1))	4.656758	10.58179	0.440073	0.6684
D(LNLLNP(-2))	-2.182946	4.344078	-0.502511	0.6252
D(LNKLNT(-1))	-0.404273	1.828784	-0.221061	0.8291
D(LNKLNT(-2))	0.701308	1.470364	0.476962	0.6427
D(LNPYR1(-1))	0.000692	0.041983	0.016488	0.9871
D(LNPYR1(-2))	-0.029607	0.042836	-0.691164	0.5038
ECM(-1)	-0.234046	0.286557	-0.816751	0.4314
R-squared	0.524177	Mean dependent var		0.006221
Adjusted R-squared	-0.600496	S.D. dependent var		0.077648
S.E. of regression	0.098233	Akaike info criterion		-1.621589
Sum squared resid	0.106147	Schwarz criterion		-0.458041
Log likelihood	57.81020	Durbin-Watson stat		1.845288

Table D 4: Mean climatic Values for Ghana

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNL)	1.041689	0.990845	1.051314	0.3157
D(LNK)	0.768039	68.30472	0.011244	0.9912
D(LNT)	-3.680034	99.49293	-0.036988	0.9712
D(LNP)	-0.021981	0.036056	-0.609645	0.5545
D(LNTYR3)	-0.035687	0.085215	-0.418785	0.6834
D(LNLLNP)	0.963444	0.562648	1.712339	0.1148
D(LNKLNT)	-1.421088	1.422066	-0.999312	0.3391
D(LNPYR1)	0.640191	0.511199	1.252332	0.2364
D(LNY(-1))	0.126990	0.287098	0.442324	0.6668
D(LNY(-2))	-0.125663	0.293116	-0.428715	0.6764
D(LNL(-1))	1.734480	1.513953	1.145663	0.2762
D(LNL(-2))	1.868408	1.291254	1.446972	0.1758
D(LNK(-1))	111.3410	75.31317	1.478373	0.1674
D(LNK(-2))	-37.62377	87.11668	-0.431878	0.6742
D(LNT(-1))	-167.2357	109.2429	-1.530861	0.1540
D(LNT(-2))	49.66009	128.6454	0.386023	0.7068
D(LNP(-1))	-0.070804	0.041973	-1.686884	0.1197
D(LNP(-2))	-0.003706	0.065428	-0.056640	0.9558
D(LNTYR3(-1))	-0.067746	0.075259	-0.900174	0.3873
D(LNTYR3(-2))	-0.169158	0.082841	-2.041962	0.0659
D(LNLLNP(-1))	-0.278415	0.358243	-0.777167	0.4534
D(LNLLNP(-2))	-1.551742	0.999986	-1.551763	0.1490
D(LNKLNT(-1))	-2.427800	2.177861	-1.114764	0.2887
D(LNKLNT(-2))	-2.638337	1.851777	-1.424760	0.1820
D(LNPYR1(-1))	-0.100988	0.157392	-0.641630	0.5343
D(LNPYR1(-2))	0.173877	0.156726	1.109434	0.2909
ECM(-1)	-0.376770	0.223176	-1.688219	0.1195

R-squared	0.660894	Mean dependent var	0.006221
Adjusted R-squared	-0.140629	S.D. dependent var	0.077648
S.E. of regression	0.082928	Akaike info criterion	-1.960323
Sum squared resid	0.075648	Schwarz criterion	-0.796775
Log likelihood	64.24613	Durbin-Watson stat	2.052983

Table D 5: Mean climatic Values for Ghana

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNL)	4.378298	3.651999	1.198877	0.2558
D(LNK)	1.380134	1.827073	0.755380	0.4659
D(LNT)	-112.0808	121.2988	-0.924006	0.3753
D(LNP)	-46.04152	179.2014	-0.256926	0.8020
D(LNTYR3)	78.56903	83.71032	0.938582	0.3681
D(LNLLNP)	6.521010	25.28800	0.257870	0.8013
D(LNKLNT)	-0.967111	1.287320	-0.751259	0.4683
D(LNPYR1)	-0.031676	0.785564	-0.040322	0.9686
D(LNY(-1))	0.057537	0.398299	0.144456	0.8878
D(LNY(-2))	-0.033624	0.352028	-0.095515	0.9256
D(LNL(-1))	-1.474002	3.576433	-0.412143	0.6882
D(LNL(-2))	-1.746683	3.487605	-0.500826	0.6264
D(LNK(-1))	1.775830	1.523391	1.165709	0.2684
D(LNK(-2))	1.245232	1.216451	1.023659	0.3280
D(LNT(-1))	-11.21486	38.76404	-0.289311	0.7777
D(LNT(-2))	42.03823	44.23689	0.950298	0.3624
D(LNP(-1))	186.6068	364.9418	0.511333	0.6192
D(LNP(-2))	420.9880	331.7745	1.268898	0.2307
D(LNTYR3(-1))	9.491114	27.74453	0.342090	0.7387
D(LNTYR3(-2))	-28.11610	31.03439	-0.905966	0.3844
D(LNLLNP(-1))	-26.24941	51.47668	-0.509928	0.6202
D(LNLLNP(-2))	-59.35877	46.77377	-1.269061	0.2306
D(LNKLNT(-1))	-1.244653	1.068407	-1.164961	0.2687
D(LNKLNT(-2))	-0.871390	0.853599	-1.020842	0.3293
D(LNPYR1(-1))	0.172273	0.716579	0.240410	0.8144
D(LNPYR1(-2))	1.393203	1.979698	0.703745	0.4962
ECM(-1)	-0.015682	0.336424	-0.046613	0.9637

R-squared	0.654116	Mean dependent var	0.006221
Adjusted R-squared	-0.163428	S.D. dependent var	0.077648
S.E. of regression	0.083753	Akaike info criterion	-1.940532
Sum squared resid	0.077160	Schwarz criterion	-0.776984
Log likelihood	63.87011	Durbin-Watson stat	1.968998

Table D 6: Mean climatic Values for Cote D'Ivoire

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNL)	7.650573	3.288617	2.326380	0.0401
D(LNK)	2.594708	2.154815	1.204144	0.2538
D(LNT)	458.1294	90.93556	5.037956	0.0004
D(LNP)	0.176633	0.051995	3.397138	0.0060
D(LNTYR3)	-315.9442	65.02309	-4.858953	0.0005
D(LNLLNP)	0.015045	0.013518	1.112915	0.2895
D(LNKLNT)	-1.790259	1.513298	-1.183018	0.2617
D(LNPYR1)	-0.015755	0.013498	-1.167244	0.2678
D(LNY(-1))	0.358866	0.310250	1.156697	0.2719
D(LNY(-2))	-0.135742	0.236225	-0.574631	0.5771
D(LNL(-1))	4.345132	3.569413	1.217324	0.2490
D(LNL(-2))	-10.17830	3.278716	-3.104355	0.0100
D(LNK(-1))	1.182248	2.819764	0.419272	0.6831
D(LNK(-2))	-8.566203	2.113208	-4.053648	0.0019
D(LNT(-1))	253.5661	176.0295	1.440475	0.1776
D(LNT(-2))	1058.800	155.3004	6.817754	0.0000
D(LNP(-1))	0.050667	0.075156	0.674159	0.5141
D(LNP(-2))	-0.004376	0.060984	-0.071756	0.9441
D(LNTYR3(-1))	-173.7508	125.0157	-1.389832	0.1921
D(LNTYR3(-2))	-755.6814	110.1140	-6.862720	0.0000
D(LNLLNP(-1))	0.009386	0.014157	0.662977	0.5210
D(LNLLNP(-2))	0.002415	0.017677	0.136648	0.8938
D(LNKLNT(-1))	-0.838970	1.979904	-0.423743	0.6799
D(LNKLNT(-2))	6.022329	1.486265	4.051989	0.0019
D(LNPYR1(-1))	0.002983	0.017641	0.169101	0.8688
D(LNPYR1(-2))	-0.016894	0.018202	-0.928127	0.3733
ECM(-1)	-0.438289	0.197973	-2.213884	0.0489

R-squared	0.978724	Mean dependent var	-0.005720
Adjusted R-squared	0.928434	S.D. dependent var	0.174465
S.E. of regression	0.046672	Akaike info criterion	-3.109970
Sum squared resid	0.023961	Schwarz criterion	-1.946422
Log likelihood	86.08943	Durbin-Watson stat	1.223439

Table D 7: Maximum climatic Values for Cote D'Ivoire

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNL)	7.650573	3.288617	2.326380	0.0401
D(LNK)	2.594708	2.154815	1.204144	0.2538
D(LNT)	458.1294	90.93556	5.037956	0.0004
D(LNP)	0.176633	0.051995	3.397138	0.0060
D(LNTYR3)	-315.9442	65.02309	-4.858953	0.0005
D(LNLLNP)	0.015045	0.013518	1.112915	0.2895
D(LNKLNT)	-1.790259	1.513298	-1.183018	0.2617
D(LNPYR1)	-0.015755	0.013498	-1.167244	0.2678
D(LNY(-1))	0.358866	0.310250	1.156697	0.2719
D(LNY(-2))	-0.135742	0.236225	-0.574631	0.5771
D(LNL(-1))	4.345132	3.569413	1.217324	0.2490
D(LNL(-2))	-10.17830	3.278716	-3.104355	0.0100
D(LNK(-1))	1.182248	2.819764	0.419272	0.6831
D(LNK(-2))	-8.566203	2.113208	-4.053648	0.0019
D(LNT(-1))	253.5661	176.0295	1.440475	0.1776
D(LNT(-2))	1058.800	155.3004	6.817754	0.0000
D(LNP(-1))	0.050667	0.075156	0.674159	0.5141
D(LNP(-2))	-0.004376	0.060984	-0.071756	0.9441
D(LNTYR3(-1))	-173.7508	125.0157	-1.389832	0.1921
D(LNTYR3(-2))	-755.6814	110.1140	-6.862720	0.0000
D(LNLLNP(-1))	0.009386	0.014157	0.662977	0.5210
D(LNLLNP(-2))	0.002415	0.017677	0.136648	0.8938
D(LNKLNT(-1))	-0.838970	1.979904	-0.423743	0.6799
D(LNKLNT(-2))	6.022329	1.486265	4.051989	0.0019
D(LNPYR1(-1))	0.002983	0.017641	0.169101	0.8688
D(LNPYR1(-2))	-0.016894	0.018202	-0.928127	0.3733
ECM(-1)	-0.438289	0.197973	-2.213884	0.0489

R-squared	0.978724	Mean dependent var	-0.005720
Adjusted R-squared	0.928434	S.D. dependent var	0.174465
S.E. of regression	0.046672	Akaike info criterion	-3.109970
Sum squared resid	0.023961	Schwarz criterion	-1.946422
Log likelihood	86.08943	Durbin-Watson stat	1.223439

Appendix F

Results of the Various Diagnostic Tests Statistic

Table F 1: Nigeria Mean **Dataset**

VAR Residual Normality Tests

Component	Skewness	Chi-sq	df	Prob.
1	0.266815	0.462736	1	0.7463
2	0.329532	0.705843	1	0.6408
3	0.130580	0.110832	1	0.8392
4	0.848421	4.678814	1	0.5305
5	1.008803	6.614938	1	0.6101
6	-0.135911	0.120067	1	0.4290
7	0.183891	0.219804	1	0.6392
8	0.095244	0.058965	1	0.8281
9	-0.271300	0.478423	1	0.4891
Joint		13.45042	9	0.7433

Component	Kurtosis	Chi-sq	df	Prob.
1	2.439708	0.510132	1	0.8451
2	2.420534	0.545644	1	0.6401
3	3.788111	1.009317	1	0.7151
4	3.720360	0.843242	1	0.4385
5	4.543458	3.871177	1	0.7491
6	4.206012	2.363504	1	0.6142
7	3.216386	0.076087	1	0.7127
8	3.196692	0.062868	1	0.4080
9	3.755312	0.927057	1	0.3356
Joint		10.20903	9	0.8338

Component:	Jarque-Bera	df	Prob.
1	0.972868	2	0.7148
2	1.251486	2	0.6349
3	1.120149	2	0.6112
4	5.522055	2	0.5132
5	10.48611	2	0.7053
6	2.483571	2	0.8889
7	0.295891	2	0.7625
8	0.121832	2	0.8409
9	1.405480	2	0.4952

Joint	23.65945	18	0.8165

VAR Residual Portmanteau Tests for Autocorrelations

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	79.57802	NA*	81.67218	NA*	NA*
2	168.6013	NA*	175.5075	NA*	NA*
3	247.6787	0.0000	261.1747	0.0000	81
4	343.8999	0.0000	368.3926	0.0000	162
5	417.3957	0.0000	452.6966	0.0000	243
6	501.5139	0.0000	552.1091	0.0000	324
7	589.4264	0.0000	659.2524	0.0000	405
8	650.9330	0.0000	736.6316	0.0000	486
9	725.3663	0.0000	833.3950	0.0000	567
10	804.2140	0.0000	939.4315	0.0000	648
11	882.4288	0.0001	1048.374	0.0000	729
12	940.7224	0.0010	1132.575	0.0000	810

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

Var residual Test

Lags	LM-Stat	Prob
1	122.7950	0.0019
2	110.4816	0.0164
3	104.3932	0.0412
4	100.9099	0.0064
5	81.56260	0.0616
6	101.1423	0.0644
7	129.1296	0.0005
8	68.35323	0.0407
9	85.35638	0.0488
10	100.4995	0.0501
11	117.5867	0.0049
12	76.35644	0.6253

Probs from chi-square with 81 df.

Table F 2: Nigeria Maximum **Dataset**

VAR Residual Normality Tests

Component	Skewness	Chi-sq	df	Prob.
1	0.468800	1.428527	1	0.2320
2	1.085943	7.665270	1	0.8056
3	0.198009	0.254850	1	0.7137
4	-0.738991	3.549705	1	0.6596
5	-0.252967	0.415949	1	0.8190
6	-0.174503	0.197933	1	0.5564
7	-0.181758	0.214734	1	0.6431
8	0.260086	0.439691	1	0.7073
9	0.443825	1.280371	1	0.2578
Joint		15.44703	9	0.7194

Component	Kurtosis	Chi-sq	df	Prob.
1	3.259409	0.109351	1	0.8409
2	5.379860	9.203570	1	0.5024
3	3.303763	0.149942	1	0.7186
4	3.752902	0.921150	1	0.8372
5	3.808051	1.061037	1	0.7030
6	2.846246	0.038415	1	0.6446
7	2.739088	0.110622	1	0.6394
8	4.105463	1.985829	1	0.5588
9	4.276387	2.647391	1	0.4037
Joint		16.22731	9	0.0123

Component	Jarque-Bera	df	Prob.
1	1.537878	2	0.4635
2	16.86884	2	0.6002
3	0.404793	2	0.8168
4	4.470855	2	0.5069
5	1.476986	2	0.4778
6	0.236348	2	0.8885
7	0.325356	2	0.8499
8	2.425519	2	0.2974
9	3.927763	2	0.1403
Joint	31.67434	18	0.7240

VAR Residual Portmanteau Tests for Autocorrelations.

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	84.96235	NA*	87.19820	NA*	NA*
2	161.8677	NA*	168.2606	NA*	NA*
3	232.7080	0.0000	245.0043	0.0000	81
4	320.4022	0.0000	342.7207	0.0000	162
5	421.8756	0.0000	459.1166	0.0000	243
6	511.8229	0.0000	565.4179	0.0000	324
7	612.9926	0.0000	688.7185	0.0000	405
8	674.1294	0.0000	765.6326	0.0000	486
9	744.8769	0.0000	857.6043	0.0000	567
10	823.1179	0.0000	962.8249	0.0000	648
11	896.7465	0.0000	1065.379	0.0000	729
12	973.3783	0.0001	1176.069	0.0000	810

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

VAR Residual Serial Correlation LM Tests

Lags	LM-Stat	Prob
1	142.9931	0.0000
2	91.90524	0.1913
3	75.43839	0.0535
4	128.1817	0.0007
5	113.7252	0.0096
6	120.3475	0.0030
7	148.9980	0.0000
8	83.26929	0.0095
9	105.4083	0.0356
10	113.3484	0.0103
11	138.9111	0.0001
12	164.9906	0.0000

Probs from chi-square with 81 df.

Table F 3: Ghana Mean **Dataset**

VAR Residual Normality Tests

Component	Skewness	Chi-sq	df	Prob.
1	0.305685	0.607380	1	0.7358
2	0.865435	4.868351	1	0.6274
3	-0.244796	0.389512	1	0.8326
4	-0.157084	0.160391	1	0.5888
5	-0.124537	0.100812	1	0.5509
6	0.055984	0.020372	1	0.7165
7	0.499194	1.619767	1	0.8031
8	0.073518	0.035132	1	0.4513
9	-0.096239	0.060202	1	0.8062
Joint		7.861919	9	0.8051

Component	Kurtosis	Chi-sq	df	Prob.
1	2.709409	0.137220	1	0.5111
2	4.731097	4.869634	1	0.6273
3	3.466285	0.353310	1	0.7522
4	2.703717	0.142648	1	0.7057
5	3.960074	1.497831	1	0.5210
6	4.353293	2.976029	1	0.6845
7	4.533605	3.821909	1	0.8506
8	4.698853	4.689913	1	0.4303
9	3.589591	0.564879	1	0.5523
Joint		19.05337	9	0.7627

Component	Jarque-Bera	df	Prob.
1	0.744600	2	0.6891
2	9.737985	2	0.7077
3	0.742822	2	0.8198
4	0.303039	2	0.6094
5	1.598643	2	0.7496
6	2.996401	2	0.6235
7	5.441676	2	0.8258
8	4.725045	2	0.4942
9	0.625081	2	0.7316
Joint	26.91529	18	0.7106

VAR Residual Portmanteau Tests for Autocorrelations.

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	83.56009	NA*	85.75904	NA*	NA*
2	160.9077	NA*	167.2877	NA*	NA*
3	233.1328	0.0000	245.5315	0.0000	81
4	315.7920	0.0000	337.6375	0.0000	162
5	402.3111	0.0000	436.8799	0.0000	243
6	482.6829	0.0000	531.8647	0.0000	324
7	554.0499	0.0000	618.8434	0.0000	405
8	618.9845	0.0000	700.5352	0.0000	486
9	694.4303	0.0002	798.6148	0.0000	567
10	774.1914	0.0005	905.8796	0.0000	648
11	840.9271	0.0025	998.8330	0.0000	729
12	900.9804	0.0140	1085.577	0.0000	810

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution.

VAR Residual Serial Correlation LM Tests.

Lags	LM-Stat	Prob
1	125.7817	0.0011
2	93.61559	0.1597
3	83.84855	0.0122
4	86.33873	0.0218
5	91.60958	0.1972
6	90.39118	0.2227
7	82.22924	0.0410
8	77.96652	0.0149
9	102.9203	0.0506
10	98.08655	0.0051
11	101.4214	0.0620
12	101.0444	0.0152

Probs from chi-square with 81 df.

Table F 4: Ghana Maximum Values

VAR Residual Normality Tests

Component	Skewness	Chi-sq	df	Prob.
1	-0.160606	0.167664	1	0.8122
2	0.636237	2.631181	1	0.6048
3	-1.600059	16.64123	1	0.7000
4	0.162625	0.171905	1	0.8104
5	-0.619180	2.491995	1	0.9144
6	-0.271334	0.478543	1	0.2891
7	0.497593	1.609390	1	0.8106
8	0.142056	0.131170	1	0.7172
9	-0.720383	3.373187	1	0.5663
Joint		27.69627	9	0.7411

Component	Kurtosis	Chi-sq	df	Prob.
1	4.537061	3.839157	1	0.7501
2	6.041035	15.02782	1	0.6700
3	6.948243	25.33152	1	0.8900
4	5.271300	8.383058	1	0.7038
5	4.496001	3.636781	1	0.6565
6	4.938425	6.105925	1	0.5135
7	4.520100	3.754892	1	0.5527
8	3.434710	0.307081	1	0.8795
9	4.112884	2.012578	1	0.4560
Joint		68.39881	9	0.6980

Component	Jarque-Bera	df	Prob.
1	4.006820	2	0.7349
2	17.65900	2	0.8001
3	41.97275	2	0.7080
4	8.554963	2	0.8139
5	6.128776	2	0.6467
6	6.584468	2	0.8372
7	5.364282	2	0.8684
8	0.438251	2	0.8032
9	5.385766	2	0.6677
Joint	96.09508	18	0.7980

VAR Residual Portmanteau Tests for Autocorrelations.

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	52.87411	NA*	54.26554	NA*	NA*
2	140.2680	NA*	146.3835	NA*	NA*
3	228.2494	0.0000	241.6966	0.0000	81
4	321.9718	0.0000	346.1301	0.0000	162
5	408.0633	0.0000	444.8821	0.0000	243
6	497.9580	0.0000	551.1213	0.0000	324
7	539.7782	0.0000	602.0897	0.0000	405
8	632.2755	0.0000	718.4572	0.0000	486
9	693.5935	0.0002	798.1706	0.0000	567
10	767.3424	0.0008	897.3502	0.0000	648
11	821.9045	0.0093	973.3475	0.0000	729
12	883.4667	0.0368	1062.271	0.0000	810

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

VAR Residual Serial Correlation LM Tests.

Lags	LM-Stat	Prob
1	387.1584	0.0000
2	112.8866	0.0111
3	99.94954	0.0752
4	108.3980	0.0228
5	95.72625	0.1261
6	106.0904	0.0322
7	58.15577	0.9741
8	102.4169	0.0542
9	90.19036	0.2271
10	144.6730	0.0000
11	78.94747	0.5438
12	109.2696	0.0199

Probs from chi-square with 81 df.

Table F 5: Cote D'Ivoire Mean **Dataset**

VAR Residual Normality Tests

Component	Skewness	Chi-sq	df	Prob.

1	0.205738	0.275134	1	0.8799
2	0.114440	0.085127	1	0.7105
3	0.085946	0.048014	1	0.6166
4	0.884710	5.087622	1	0.8241
5	0.210957	0.289269	1	0.4907
6	0.338921	0.746638	1	0.8175
7	0.400560	1.042916	1	0.7671
8	0.103766	0.069988	1	0.7114
9	0.406675	1.075001	1	0.6998
Joint		8.719710	9	0.8436

Component	Kurtosis	Chi-sq	df	Prob.
1	2.544891	0.336577	1	0.6518
2	2.184262	1.081322	1	0.7284
3	2.615602	0.240113	1	0.8241
4	3.630836	0.646675	1	0.7213
5	5.495746	10.12172	1	0.6015
6	3.645355	0.676785	1	0.8107
7	2.737609	0.111880	1	0.7380
8	2.572281	0.297283	1	0.5856
9	3.722245	0.847662	1	0.3572
Joint		14.36002	9	0.0101

Component	Jarque-Bera	df	Prob.
1	0.611710	2	0.8365
2	1.166450	2	0.6501
3	0.288127	2	0.6058
4	5.734296	2	0.7569
5	10.41099	2	0.8055
6	1.423423	2	0.4908
7	1.154796	2	0.5014
8	0.367272	2	0.8322
9	1.922663	2	0.3824
Joint	23.07973	18	0.8185

VAR Residual Portmanteau Tests for Autocorrelations.

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	66.00396	NA*	67.74091	NA*	NA*
2	137.8323	NA*	143.4519	NA*	NA*
3	220.3235	0.0000	232.8174	0.0000	81
4	300.5524	0.0000	322.2153	0.0000	162
5	376.5224	0.0000	409.3573	0.0000	243
6	445.5276	0.0000	490.9089	0.0000	324
7	507.6368	0.0004	566.6045	0.0000	405
8	577.9306	0.0025	655.0387	0.0000	486
9	631.4141	0.0311	724.5671	0.0000	567
10	676.1919	0.2146	784.7856	0.0002	648
11	739.6898	0.3836	873.2291	0.0002	729
12	786.0906	0.7202	940.2525	0.0010	810

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

VAR Residual Serial Correlation LM Tests.

Lags	LM-Stat	Prob
1	101.7521	0.0503
2	112.7780	0.0113
3	115.0225	0.0077
4	110.7194	0.0158
5	93.67748	0.0586
6	98.51834	0.0102
7	105.0477	0.0375
8	91.24128	0.2047
9	73.67796	0.0057
10	57.01449	0.0102
11	84.36183	0.3772
12	103.3926	0.0474

Probs from chi-square with 81 df.

Table F 6: Cote D'Ivoire Maximum **Dataset**

VAR Residual Normality Tests.

Component	Skewness	Chi-sq	df	Prob.

1	0.111165	0.080325	1	0.8169
2	0.658279	2.816649	1	0.7033
3	0.406031	1.071598	1	0.3906
4	0.323603	0.680675	1	0.8394
5	0.402504	1.053062	1	0.6948
6	0.686419	3.062611	1	0.7801
7	0.231554	0.348513	1	0.6550
8	1.690461	18.57478	1	0.5700
9	-0.432338	1.214956	1	0.8104
Joint		28.90317	9	0.8607

Component	Kurtosis	Chi-sq	df	Prob.
1	3.277848	0.125449	1	0.7232
2	2.891641	0.019080	1	0.8901
3	2.601035	0.258656	1	0.6110
4	10.78426	98.46627	1	0.6230
5	3.643675	0.673266	1	0.4119
6	3.420901	0.287882	1	0.5916
7	4.070556	1.862396	1	0.1723
8	7.775376	37.05684	1	0.6732
9	2.818795	0.053358	1	0.8173
Joint		138.8032	9	0.8100

Component	Jarque-Bera	df	Prob.
1	0.205774	2	0.9022
2	2.835729	2	0.2422
3	1.330254	2	0.5142
4	99.14695	2	0.8700
5	1.726328	2	0.4218
6	3.350493	2	0.1873
7	2.210909	2	0.4311
8	55.63162	2	0.7900
9	1.268313	2	0.5304
Joint	167.7064	18	0.7850

VAR Residual Portmanteau Tests for Autocorrelations.

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	76.69048	NA*	78.70865	NA*	NA*
2	140.2895	NA*	145.7454	NA*	NA*
3	207.0811	0.0000	218.1030	0.0000	81
4	292.1039	0.0000	312.8427	0.0000	162
5	361.2547	0.0000	392.1628	0.0000	243
6	436.2428	0.0000	480.7851	0.0000	324
7	519.8244	0.0001	582.6501	0.0000	405
8	580.8456	0.0020	659.4188	0.0000	486
9	647.0547	0.0109	745.4906	0.0000	567
10	721.2972	0.0237	845.3340	0.0000	648
11	778.3918	0.0998	924.8585	0.0000	729
12	825.1522	0.3480	992.4013	0.0000	810

*The test is valid only for lags larger than the VAR lag order.
df is degrees of freedom for (approximate) chi-square distribution

VAR Residual Serial Correlation LM Tests

Lags	LM-Stat	Prob
1	118.5592	0.0042
2	104.3670	0.0413
3	79.62614	0.5224
4	83.98605	0.3882
5	80.19654	0.5043
6	77.42005	0.5921
7	106.5304	0.0302
8	67.73893	0.8535
9	114.6584	0.0082
10	99.93258	0.0754
11	90.38889	0.2228
12	80.48001	0.4954

Probs from chi-square with 81 df.