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Climate Change Effects on Cocoa Export: Case study of Cote d'Ivoire

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Abstract

This paper attempts at examining the long-run effect of climate change on export revenue of the cocoa industry of Cote d'Ivoire. We apply an Autoregressive Distributed Lag (ARDL) approach using time-series data for a period of 45 years from 1966-2011 to investigate this phenomenon. The results indicate that precipitation may affect cocoa export revenues in the Ivorian economy. This finding, in accordance with the Jones and Olken (2010) study, supports the notion of the adverse effects of precipitation on exports in least developing countries.

Keywords: Cote d'Ivoire, climate change, cocoa exports

JEL: Q17, N77

Throughout the past decades, climate change impact around the globe has continuously gained ground. Precipitation effects from rainfall, hail, sleet, and drizzle due to climate change are slowly altering climatic conditions. In agriculturally-dependent economies especially, there is a growing concern over this issue with respect to subsistent and more importantly commoditized agricultural output. With these economies now experiencing new weather patterns through different exogenous and intrinsic environmentally related phenomena, production has plummeted at varying degrees in different agricultural sectors and economies. Fluctuating weather now leads to erratic rainfall levels, increased environmental hazards and may affect economic growth by impeding upon export volumes of agricultural produce. This unstable supply of rain engenders different effects on production factors in different geographical locations. In certain areas, where there is excess (rainfall), it sometimes leads to agricultural related shortages, e.g., failed irrigation, floods, landslides and other closely linked occurrences. Also, areas lacking water have ended up with severe shortages, crop failures, and drought. In light of these observations Gupta, Sen, and Srinivasan (2012) argue that come 2030, the rainfall level around the globe will have risen in comparison to today's volume. In the case of Cote d'Ivoire, the marked increase and or variability in precipitation and other climatic incoherencies may impact its agricultural sector by affecting the total cocoa production, especially its export earnings thereof. These environmental challenges are not only significant to Cote d'Ivoire's economy but to the entire global cocoa industry as well. The reason in part is because the Ivorian cocoa sector is at the helm of worldwide cocoa production and export – *accounts for over a third of global supply and nearly half of all its export earnings* – hence the clarion call to address this challenge.

One of the most important production factor inputs for agricultural processes besides land is the weather effect. In the case of cocoa, a tropical cash crop, the quantity, and regularity of rainfall are essential determinants because of the direct effect on the final yield. However, previous studies, to the best of our knowledge have not been addressed in this light, to examine the long-term effects and implications of such precipitation changes on the volume of cocoa exports in the Ivorian economy. According to (WCF) World Cocoa Foundation, production in leading African cocoa producing nations declined from 5.8 % in 2009 to 8.9 % in 2012 due to recurring drought episodes in some parts of West Africa. With such a drop, commodity forecasts on the volume of cocoa to be produced by these African nations have become unreliable; especially for the important Ivorian cocoa-producing sector. In Cote d'Ivoire, an agricultural-based economy, cocoa is the buttress of the agricultural sector and a major contributor to its gross domestic product (GDP). According to the Ivorian Ministry of Economy and Finance, cocoa revenues account for about 12% of the GDP, and the sector employs three-quarters of the active working population. Singlehandedly, Cote d'Ivoire is responsible for over 38% of world cocoa production and is ranked first among all cocoa producing nations globally per the International Cocoa Organization (ICCO).

Taking these into account, the inference we draw from some of the facts as mentioned earlier is that the Ivorian cocoa sector is key to its economy. Therefore, given the perceived climate/weather effect via erratic annual rainfall, we conjecture a deleterious impact on Ivorian cocoa export as well as to revenue streams thereof. Also, due to the independently set commodity prices on the international market, the likelihood of an economic recession due to perceived underlying macroeconomic instability is observed; like a fall in demand, a rise in unemployment, rise in inflation, restricted access to credit and deteriorating terms of trade. This international commodity pricing is because producer countries are vulnerable to these global price determinations and hence stand the risk of making considerable losses from foregone profits and possible windfalls, especially during favorable production cycles. It is thus imperative that, given this already existing disadvantageous situation, steps be taken to avert this growing phenomenon of climate change on Ivorian cocoa exports, to enable well prescribed and favorable mid-to-long-term policies, so as to nip this foreboding ailment in the bud.

Cocoa, a tropical crop imported by the French during the colonial period to Cote d'Ivoire was produced based on a protectorate agreement. Initially, local farmers were conscripted to grow cocoa and then the harvests exported to the European market. After a century, the agreement became null and void. However, these farmers had acquired expertise in cocoa production and the demand for this product was increasing. A memorandum of understanding was signed based on an agreement in which the farmers produced the cocoa beans, and the French provided development assistance to succor its production to serve foreign markets. Nowadays the production quantity keeps burgeoning and is assumed that this assistance might have influenced the total volume of harvest. This increase automatically implies a rise in the export of cocoa beans and seems development assistance contributes to boosting cocoa exports.

This study makes use of time series analyses and seeks to analyze the impact of climate change through precipitations on the export revenues of cocoa in Cote d'Ivoire from 1966-2011. The current study aims at demonstrating that rainfall affects cocoa exports and by extension its revenues. We hypothesize that there is possibly an adverse impact of rainfall (precipitation) on cocoa export earnings through the decline of cocoa exports. Also, we are of the opinion that, this study will steer ongoing debates on the real effect of climate change on crop production, especially in African nations. We use export revenue earnings from exporting cocoa, official development assistance (ODA), and the annual harvest of cocoa beans as the control variables. We also include the exchange rate. An Autoregressive Distributed Lag (ARDL) is employed to check if there is a long-run relationship between the variables and the long run effect of precipitation on export revenues of cocoa.

Next, the paper is structured as follows: the literature review, data and methodology in the next section, and further, the empirical results of the investigation. Finally, we conclude with some proposals to inform policy makers.

Literature review

Many previous studies conducted, have demonstrated in numerous instances how high risks associated with agricultural production negatively expose the cultivation of certain crops (cash crops) compared to other crops. These studies distinguish their individual perspective on the hypothesis of climate change effects on crop production and how it leads to potential export revenue risk.

The impact of Climate change on agriculture has attracted researchers' attention in the case of its considered and possible adverse implications in the past few years. The main existing research focused on regional agricultural sector investigation, and national investigation on a particular agricultural crop. Sung-No Niggol Seo (2005) studied the impact of climate change on agriculture in Sri Lanka. A cross-sectional method is applied to investigate the impact of rain on agricultural sector using monthly data. In the model, climate change variables such as temperature, and precipitation were used to estimate the regression and the results found were that an increase in rain in the month of September is harmful. Ochuodho, Landtz and Olale (2015) focused their research on the economic impacts of climate change on two sectors. The forest and agriculture sectors in Canada, using a dynamic multi-regional computable general equilibrium model analysis over a period from 2006-2051. Thus, they found a negative impact of climate change on the majority of these regions is through economic indicators like gross domestic product, income, imports, terms-of-trade, capital, and total output. Valverde, Serralheiro, De Carvalho, Maia, Oliveira and Ramos (2014) examined climate change impacts on irrigated agriculture in Portugal. They conducted a study on the potential future impact of climate based on the current state. The ISAREG simulations were implemented using water requirements and the results indicated less sensitivity to climate change. Against this finding, Chen and Xu (2014) broadly evaluated the impact of climate change on agriculture in China to propose a strong policy against climate change. Corn and soybean yields are used to investigate the relationship with the weather, and it was discovered that global warming has caused an economic loss, and projected to decline the returns. Robert Mendelsohn (2014) conducted a study in the Asian region to check whether climate change impacts agriculture. Using a Ricardian model, permitted to conclude that among the Asian countries in the sample, India was predicted to be vulnerable. Calzadilla, Zhu, Rehdanz, M.L. Parry (2004) analyze the global consequences on crop production due to climate change. They indicated that it might result in an imminent risk of hunger. A panel study was conducted following the use of a transfer function to the production model, and then a simulation model was done. The production model accounted for the changes in the precipitation and temperature. Wheat, rice, maize, and soybean were considered as crop yields used in the study. They found that climate change sharply decreases regional and global production with a significant loss of 30% in Africa by 2080, and that leads to a risk of hunger. Tol and Ringler (2014) looked at the two-sided effect of higher temperature and less rainfall as a result of climate change. It was predicted to affect the South African agricultural sector productivity, and international trade patterns.

A study conducted by Cynthia and Rosenzweig (2002) intended to prove the tangible effect of precipitation on crop production in the U.S. Among several crops maize was selected to experiment if climate change via torrential rains could lead to a damage of corn harvest. The study used data from the period of 1951-1998, and a simulation was conducted to analyze the level of precipitation and only precipitation on maize growth. They found that heavy rainfall due to climate change damaged crop production. In the long-run, the probability of harm could be more than 90% in 2030 based on the current cost. A study by Jody Freeman (2009) mentioned the shocks to international trade caused by climate change. The effects of climate change on foreign countries could lead to a damage of the American economy. First of all the trade balance may decrease, further climate change may have harmful effects on American exports and increase imports from foreign countries. Following the same idea Jones and Olken (2010) recently argued about the link between exports and climate change. In the conducted study, widespread attention is put on international trade to measure the effects of climate shocks on the economy. The analysis was carried out using a dataset of the United States and the rest of world using exports, temperature, and precipitation as the variables. A feasible generalized least squares method was employed to demonstrate that there was an adverse effect of high temperature on exports in developing countries. At the same time, they noticed a modest impact of precipitation on exports for developing countries, and they finally found that it was not robust compared to the effect of temperature. A commodities export economy is opened to grave losses from agriculture due to unreliable production (Agim Binaj, 2014). This observation points out the export policy for raw materials. Does the export of crops lead to economic growth in a developing economy, in particular, Cote d'Ivoire? Many types of studies argue that export economies are valuable for the diversification of the economy in the developing and or developed countries. Hyunsoo Kang (2015) conducted a time-series study in the four major rice producing countries to check for evidence export-led growth. He used an augmented Solow production model in investigating the effects of agricultural exports on gross domestic product (GDP). Particular attention was paid to the rice exports, agricultural exports, and non-agricultural exports covering a data period of 31 years. After running stationarity tests with ADF, the study implements a VECM and Granger Causality. He found that rice exports contribute to economic growth. Along the same lines, Ohlan Ramphul (2013) investigated the causality between agricultural exports and gross domestic product (GDP) from 1970 to 2011. He applied the Granger Causality method to find that there was a unidirectional causality in which exports cause GDP growth.

This study attempts to contribute to existing literature in several ways. We present a comprehensive and more concise model analyzing the exportation of a major cash crop, cocoa, due to its significant contribution to the Ivorian GDP and the cocoa supply around the world. We also take into consideration all the influencing factors that may affect cocoa export revenues by considering climate change effect. Finally, we analyze the impact of climate change on cocoa exports for Cote d'Ivoire.

Data and Methodology

The data on agricultural variables is from FAO (Food and Agriculture Organization) that spans a period of 1966-2011. This time series dataset is country-level annual data in which we consider cocoa production and cocoa exports revenue. Climate data such as temperature and precipitation is from CLIMPAG (Climate Impact on Agriculture) database. Further, other economic data were collected from World Development Indicators (World Bank 2015) to control for the effectiveness of the output used in the model from the agricultural export. The study also considers the exchange rate between the US dollar and the Franc CFA (XOF), and finally data on official development assistance (ODA).

The dependent variable used is the logarithm of export values of cocoa (measured in US dollars) for each of the specific cash crops. The listed main independent variables in logarithms are production and precipitation, and some control variables are considered to render the model robust, such as the exchange rate and ODA.

The effect of precipitation on cocoa export activity

Here we implement the practical framework for the analysis of the climate change determinants and other macroeconomic data to analyze their impact on cocoa exports' revenue in Cote d'Ivoire, and we consider a variety of robust regressions. In this section, the empirical framework assumes a simple open economy theory, and is written as:

$$Y_t = F\ (ODA, P, I, C) \qquad (1)$$

$$C = K\ (T, PR) \qquad (2)$$

$$I = G\ (IP, EX) \qquad (3)$$

Where Y the aggregate output, a measure of the export revenue of cocoa beans, which is a function of (ODA) official development assistance. C climate variable, capturing rainfall variation through weather patterns. P the total production of cocoa in tons, and I, the domestic price measures exchange rate (EX) and (IP) international price level. Basically equation (1) captures the effect-level of ODA, climate, production and price on cocoa exports, therefore, we can perceive how these factors affect revenue from total cocoa output. Equation (2) and (3) respectively, describe the determinants of climate change and international price. The variable T measures temperature and PR for precipitation (rainfall measurements) which covers the Ivorian climate space. Finally, I the domestic price level, measures international price and EX, the exchange rate of Cote d'Ivoire's local currency the West African Francs CFA (XOF).

By replacing equation (2) and (3) in equation (1), Y can be redefined and specified as:

$$Y_t = f\ (ODA, T, PR, P, IP, EX) \qquad (4)$$

Equation (4) clearly demonstrates the link between each variable and the aggregate output. The real contribution of ODA on cocoa exports if it increases or otherwise. The impact of the weather via temperature (T) and rainfall/precipitation (PR) variations on the volume of cocoa produced per ton. Finally, the effect of the exchange rate (EX) and international cocoa price (IP) volatility.

Based on how Cote d'Ivoire became both the largest cocoa producing country and the largest global exporter, development assistance has been invaluable and consistent. Since its inception, the Cote d'Ivoire cocoa sector has mainly benefited from a steady increase in the official development assistance budget (WDI, 2015). Over the past decades, the aid package has risen considerably, therefore, justifying the fact that ODA could be one of the determinants that impact the cocoa production sector. Second, agronomists agree that rainfall is crucial for a better harvest since cocoa is a tropical crop. However, excessive rainfall or lack thereof may drastically affect production. We use precipitation to capture the amount of rain in the cocoa plantation zones. The temperature, on the other hand, has a considerable impact on the harvest (Laderach, Martinez-Valle, Schroth, and Castro, 2013) and affects the quality and quantity of the final yield. The precipitation and temperature variables translate the effect of inconsistent weather patterns in the region, and how they have led to dramatic changes in climatic conditions such as a rise in drought frequency, torrential rainfalls, topsoil erosion/depletion, and unusual humidity conditions. These different occurrences have recorded a gradual decline in the total export volume of cocoa beans in the Ivorian agricultural sector. As compared to the older ones, the younger trees are more vulnerable due to the likelihood of higher mortality. Also, higher cocoa seed mortality is due to cocoa-seed-related diseases, landslides in cocoa-cultivating regions, poor irrigation techniques, longer fermentation periods and mold which are all factors of precarious rates of rainfall and to some extent temperature variations. These aspects justify the need for our use of a climate change variable to justify the nexus between it and aggregate cocoa yields. Since cocoa commodity price determination is independent of Cote d'Ivoire's cocoa production sector but highly dependent on the prevailing international exchange rate, between the US dollar and the XOF, transactions are conducted through cocoa futures contracts on the commodity market in New York (ICE – USD). It is essential to include this measure to see how the demand for cocoa in the short and long run is subject to the intervening currency exchange rates and close cocoa export competitors. An apriori fixed cocoa selling price impacts the demand for cocoa. By determining the rate outside the Ivorian economy, cocoa producers set a domestic asking price based on the international market determined price for producers in the case of Cote d'Ivoire. On the part of the Ivorian government, they impose a minimum selling price (domestic minimum guarantee price) to shield smallholder farmers and producers from free market global price volatility between the Ivorian cocoa producers and prospective buyers. Here, the price fixation clearly demonstrates how the domestic price is strictly related only to the commodities market through the exchange rate. Also, we assume that the cocoa sector of Cote d'Ivoire has been and is still oriented only towards export of the raw cocoa bean with about 80% of total yield destined for exportation. This observation translates into a very insignificant local consumption level.

Since the degree of consumption is linked to the domestic price levels, and the local cocoa product consumption is negligible, this means product price tends to be inelastic. The result is that price levels for local produce do not include cocoa products. We also assume the Ivorian economy is heavily unindustrialized hence does not produce value-added products from its cocoa beans locally thereby reinforcing the weak link between a possible rise in price levels of cocoa products consumed domestically and the demand for cocoa beans by exporters. A generalized increase in prices is not foreseeable in the short term and given the assumption of the Ivorian economy being export oriented in the quick long run there is equally no perceived inflationary threat.

Based on equation four, and as per Laderach, Martinez-Valle, Schroth, and Castro (2013), the impact of precipitation especially rainfall has a significant impact than temperature changes in the case of Cote d'Ivoire. Therefore our final variable takes into account only the direct effect of precipitation on cocoa output levels and related revenue streams.

The ARDL model

Descriptive analysis of ARDL allows researchers to investigate long-run and short relationships. Autoregressive Distributed Lag (ARDL) approach uses time series data to regress a dynamic equation. It also requires stationary variables with an integration order one which is denoted by I (1). We used time series data to highlight the economic questions mentioned in this paper. Time series is useful for estimating national aggregates at specific points in time. We apply time series data of a set of macroeconomic data as well as a rainfall/precipitation climatic factor on cocoa exports revenues in Cote d'Ivoire to reveal the aggregate volume of cocoa exports at an annual frequency through a period of 45 years. The simple econometric model can be specified as:

$$Y_t=\alpha+\boldsymbol{\delta}t+P_1 Y_{t-1}+\ldots+P_p Y_{t-p}+\beta_0 X_t+\beta_1 X_{t-1}+\ldots+\beta_q X_{t-q}+\varepsilon_t \quad (4.1)$$

Where Yt is a dependent variable which is a function of lag variables of itself such as Yt-1 until Yt-p and on the independent variables Xt, Xt-1 until Xt-q. Time series analysts have different analytical approaches which are broader and more restrictive. However, techniques used by this econometric model can lead to an incorrect result (Beck, 1995) so, using time series data requires an adequate methodology. The Box & Jenkins estimation of time series parameters posits to start with the identification step. For example, Greene (2000) found that ergodicity in the theory of estimation, when it is identified with stationarity, you get a better estimation. Horst (2000) described how an Ordinary Least Square (OLS) estimator could be affected by the diagnostics. He argued that serial autocorrelation causes the OLS estimator to lose its property of efficiency. Therefore, the procedures applied should help the model to avoid common problems in econometric analysis, as cited above, and also in underestimating equation and incorrect standard errors and so on.

To follow all the requirements for estimating a dynamic regression equation, a linear dynamic regression model (William Greene 2000, Horst, 2000) is essential. ARDL is an econometric model developed and modified to apply time series data. The model was introduced in the seminal article by Granger (1981) and later improved upon by Weiss (1983) and Engel (1987). It details the complexity involved in using time series data. This model and method of estimation has proven indispensable to the development of econometric theory (Stock, 1999; Robert and Yoo, 1987; Robert and Granger, 1987; John, Granger, Weiss, Todd, 1995; Titus, 2009; Jungho, 2007; Gustavo, 2012; Muhammad et al., 2011). The ARDL model is both efficient and highly relevant to the estimation of econometric trends. From the perspective of the researcher, there are two different and significant periods that must be measured, namely the short term and the long term. Therefore, it is meaningful to know and understand the real impact of a phenomenon over periods varying between 10 to 50 years. With the ARDL approach, it is possible to gain a clear understanding of changes over time and to interpret likely outcomes in time. James (1997) highlights the function of the ARDL approach. He sees it as a broad and robust framework for studying both long-run and short-run relationships.

Many agricultural economic papers have used the ARDL approach to investigate the sector because of the efficiency of the model. The agricultural sector is important for developing countries because of its significant contribution to their GDP. This GDP component has a fundamental value especially as it relates to the size of an economy, especially in a developing country where it retains the highest percentage contribution to the economy in front of the industry and services sector. It is accepted that agriculture is a precondition to industrialization, so developing countries in general start by focusing their policies on the agricultural sector as it is the case in Cote d'Ivoire where the agricultural sector contribution was the highest from 1960 with 47.9% until 1972 with 29.8% to GDP. Due to its significant contribution, particular attention to the sector can help determine its role in the growth of the country's GDP and facilitate the industrialization process. The ARDL approach can provide a sound econometric approach to analyze the impact of climate change factors on Cote d'Ivoire's cocoa export revenues. In fact, the model can help to determine the perceived trend of future export earnings. Also, the model describes the role of several important contributing factors to the agricultural sector like foreign aid, rainfall changes, currency exchange rate on demand for cocoa output, and the international price of cocoa, and how can affect national cocoa production and export revenues. Muhammad et al. (2011) uses the Cobb-Douglas production function to establish a relationship between the financial sector and agricultural sector in Pakistan. The paper utilizes the ARDL method to estimate the long-run effects between the factors before using the causality test to check whether the factors can cause each other. In the end, he found that the factors demonstrate a long-run relationship. Sabuhi-Sabouni et al. (2008) explain how external factors affect agricultural products, particularly export products. Their study found that price fluctuations and saffron exports have a long-run relationship and that the variables are significant. Jungho (2007) uses the ARDL approach to show that there is a dynamic relationship between the United States' agricultural trade balance and the national macroeconomic aggregate. The results indicate that the exchange rate is a key determinant in the long-run, short-run, and relationship is statistically significant. In contrast, Gustavo et al. (2012) used the Herzerand Nowak – Lehnmann model to test the ARDL hypothesis on coffee beans exports and he concluded that there is a long-run relationship between diversification of export and economic growth. Titus (2009) used ARDL model to find strong evidence of a nexus between agriculture and economic growth. According to his research, agriculture is the central driving force for economic growth. Instead of the Cobb-Douglas production function, he used the Solow-Swan production function to test the real contribution of agriculture and if it is an engine for development before applying the ARDL approach. He found that trade openness based on agricultural produce had a positive impact on economic growth, thus further proving the usefulness of the ARDL approach in econometric research. ARDL is a regression model which was used to show the importance of using methods that assume the errors are generated by first order serial autoregressive process (J. Paul, 2001). It is autoregressive in the sense that it accounts for lagged values of the dependent and the explanatory variable. Grayham (1995) called it a dynamic regression in which Y_t is regressed on Y_{t-1} as X_t on X_{t-1} and we have the Gaussian error term.

J. Paul (2011) talks about the robustness of ARDL models and of them being specific by including lag selection in the equation. This addition comes to deal with immediate change and imperfect information on the data collected from different sources and frequencies. Also, Patterson and Ryding (1984) found that the distributed lag effects were pervasive and that the distributed lag affects short-run dynamics. One of the valuable tools of the ARDL model is its ability to test cointegrating equations in the analysis of time series data which gives useful predictions in the presence of long-run and short-run dynamics. It is known that the long-run builds a platform for a strong and confident analysis with stability to avoid pitfalls. In this paper, it may be meaningful to know how the ARDL model reveals the long-run equilibrium and short-run relationship between Cote d'Ivoire's cocoa export revenues and its determinants. Therefore, we based our design on William Greene (2003) to specify the ARDL equation and the model is written as:

We suppose the variables are cointegrated of order 1 denoted I(1)

$$Y_t = \mu + \sum_{i=1}^{p} YiYi - 1 + \sum_{j=1}^{r} \beta\, jXt - j + \delta\, Wt + \varepsilon\, t \quad (1) \qquad (4.2)$$

Where ε is supposed to be uncorrelated and homoscedastic; Y_t is dependent variable, Y_{i-1} is autodistributed lag of the dependent variables. X_{t-j} is a distributed lag variable of the independent variable X_t, W_t are called random walks.

From the equation (1) we get the error correction model in which we have an equilibrium relationship between the variables so it can be specified as:

$$Y_t = \mu + Y_1 Y_{t-1} + \beta_0 X_t + \beta X_{t-1} + \varepsilon_t \qquad (4.3)$$

If we suppose that Ω is called the error correction equation then we can write $\Delta Y_t = Y_t - Y_{t-1}$ so and $\Delta X_t = X_t - X_{t-1}$ from this assumption we obtain:

$\Delta Y_t=\mu+\beta_0\Delta X_t+ (Y_1-1) (Y_{t-1}-\Omega X_{t-1}) +\varepsilon_t 3)$ (4.4)

$\Omega=-(\beta_0+\beta_1)/ (Y_1-1)$, ΔY_t stands for an equilibrium relationship and

$(Y_{t-1}-\Omega X_{t-1})$ for the equilibrium error.

Those predictions mentioned can be done following ARDL model so first of all we should regress the equation in order to have estimated results and then use the diagnostics test to check whether there is a common inaccurate dynamic.

Stationary conditions

ARDL is a dynamic econometric model that necessitates a certain amount of investigation Nowak (2006), Pesaran (2001), and Carter (2008). Most of the economic variables are not stationary for a time series model. According to Greene, the precondition for time series data resides in its stationarity and level. The usefulness for checking the presence of unit roots has been identified earlier in the literature. Phillips and Peron (1988) find unit root as a theoretical implication of models which assume the rationale use of information that is available to economic agents. In the same paper, they argue that the unit root can help evaluate the nature of non-stationarity that most aggregate data show evidence of. In the same order Nason (2006) comes to the same conclusion that stationarity methods may apply in an estimation to avoid the risk of misleading answers..

Augmented Dickey-Fuller test

Most papers propose that testing the variables for stationarity issues is the first rule for dynamic estimation using time series data. Following the procedures established by the previous studies, we are going to check if our variables are stationary or not. Then we will be able to know the cointegration order of each variable used in this paper such as annual export revenues, cocoa production, precipitation, and exchange rate, ODA, yearly.

The commonly used methods to detect unit root tests are the Augmented Dickey-Fuller (ADF) test and the Philipps-Perron (PP) test. Many papers have used ADF to test their variables as well as to check the stationarity of the different variables in a definite equation. Even Pierre Perron (PP) in his paper "Testing for a Unit Root in Time Series Regression" uses ADF because it is developed for autoregressive models. ADF is extremely useful in determining stochastic and deterministic trends. Due to its importance, we applied ADF tests to our variables. This method gives the option of choosing from between the various deterministic terms (trends, constant and trend and intercept) in order to evaluate the stationary state.

We also used the PP as an alternative procedure for testing the presence of unit root in time series data.

Philips Perron test

Using the Phillips-Perron method in the analysis of unit root test has become popular in recent times. Past studies conducted by researchers (Hyungsik, 2007; Muhammad Afzal, 2010; Champia, 2013; Helmi Hamdi, 2013; Amassoma, 2013; Muhammad Imran, 2014). In fact, PP specification appears to be different from ADF because PP techniques deal with serial correlation and heteroskedasticity in error terms (Greene, 2003). Another advantage of using PP is the fact that PP tests correct for any serial correlation and heteroskedasticity in the errors of the test regression. PP tests overtake ADF because PP tests can address all forms of heteroskedasticity in the error term. In Choi (1992) conducted a study on data aggregation and it found that, in comparison to ADF, PP tests appear to be stronger than ADF in finite samples. Due to the added benefits of the PP test, we decided to use the test as an alternative measurement for our hypothesis. We also took the decision to base our final analysis on the results of the PP test. Hence, the test was used to clarify and conclude our finding from the unit root test which was conducted using the ADF method. To further strengthen the validity of our research we used two unit root tests this we believe, will show any discrepancies with our research methodology. Table 2 below shows results of ADF and PP results.

We finally produce a complete framework of our paper's analyses as follows:

$$Y_t = \beta_0 (PR_t)^{\beta_1} (P_t)^{\beta 2} (EX_t)^{\beta_3} (ODA_t)^{\beta_4} \quad (5)$$

Taking logs of equation (5) we have the static linear relation below:

$$LN (Y_t) = \beta_0 + \beta_1 LN (PR_t) + \beta_2 LN (P_t) + \beta_3 LN (EX_t) + \beta_4 LN (ODA_t) + \varepsilon_t \quad (6)$$

The above equation does not take into account the lag structures for each variables, therefore we propose an autoregressive distributed lag approach can be used to estimate our coefficients following the equation (6) regression form by adopting lag selections that will capture a dynamic interaction through a long term and short term impact of our variables under investigation:

In our case we will adopt a two-lag selection giving the following dynamic equation below:

$$LN (Y_t) = \beta_0 + \beta_1 * LN (T_t) + \beta_2 * LN (T_{t-1}) + \beta_3 * LN (PR_t) + \beta_4 * LN (PR_{t-1}) + \beta_5 * LN (P_t) + \beta_6 * LN (P_{t-1}) + \beta_7^* LN (EX_t) + \beta_8^* LN (EX_{t-1}) + \beta_9 * LN (ODA_t) + \beta_{10} * LN (ODA_{t-1}) + \varepsilon_t \quad (7)$$

Empirical Results

Table 1 gives the results of the descriptive statistics for export revenues, precipitation variable as the average of the maximum precipitation per year defined as the effect of the rainfall, official development assistance (ODA), exchange rate and production.

Table.1 Descriptive statistics

Variables	Mean	Standard Deviation	Maximum	Minimum
Y	5.71E+08	3.52E+08	1.11E+09	1.05E+08
EX	388.5263	153.8072	733.0385	211.2796
P	752668.3	460692.4	1511255.	144476.0
PR	118381.2	558209.5	2708000	51.30000
ODA	4.23E+08	4.98E+08	2.40E+09	34020000

**Authors' computation*

Table.1.1 Linearized descriptive statistics

Variables	Mean	Standard Deviation	Maximum	Minimum
Y	19.90369	0.793490	20.83075	18.47105
EX	5.888075	0.387060	6.597198	5.353182
P	13.28269	0.774751	14.22845	11.88087
PR	6.770383	1.812090	14.81172	3.937691
ODA	19.25096	1.139946	21.59940	17.34246

Table 2 gives the results of the unit root test using the Augmented Dickey Fuller test (ADF) for the respective variables used in the model. The specified model of time series used in this investigation requires checking if all the variables are stationary or not. Another alternative has been applied to support the ADF method. For that, Phillips-Perron (PP) is employed to corroborate the robustness of the results found in table2.

Table2: Results of Unit Root Test

Variables	ADF		PP	
	Level	**First Difference**	**Level**	**First Difference**
LOGER	-1.788(0.381)	-10.82(0.000)***	-1.178(0.676)	-12.37(0.000)***
LOGODA	-1.845(0.354)	-9.088(0.000)***	-1.602(0.473)	-9.234(0.000)***
LOGPR	-0.845(0.796)	-6.895(0.000)***	-0.845(0.796)	-6.895(0.000)***
LOGEX	-1.335(0.605)	-5.784(0.000)***	-1.425(0.5618)	-5.787(0.000)***
LOGP	-1.319(0.612)	-8.958(0.000)***	-1.916(0.322)	-9.419(0.000)***

*The t ratio values are in parentheses; *** indicates significance at the 1% level and the lag order of ADF and PP are respectively by selected Schwarz Info Criterion(SIC) and Newey-West Bandwidth(NWB)*

First, the results show all the variables are not significant at the 10% level so the null hypothesis is accepted and after first difference all the variable are significant at the 1% level then the null hypothesis can be rejected and we conclude that cocoa exports revenues, precipitation, ODA, exchange rate, and cocoa production are non-stationary. As a result, the ARDL bounds test can be implemented because the stationary order should be order zero or one.

We applied the ARDL method with a lag order 2 and for checking the presence of long-run a bounds test is necessary. Table 3 reveals the bounds F test if there is cointegration or not, in this case we see that the F test value is 12.923 and it is bigger than I_0 (lower) Bound and I_1 (upper) Bound value hence there is a cointegration at the 1% level among our variables.

Table3: ARDL Bounds test

Test Statistic	**Value**	**K**
F statistic	12.923	4
Critical value Bounds		
Significance	I_0 Bound	I_1 Bound
10%	2.45	3.52
5%	2.86	4.01
1%	3.74	5.06

Table 4 and table 5 give the regression results for the short-run and long-run relationship among the variables. From table 4 two of the variables negatively affect the export revenues from cocoa output, ODA and precipitation are statistically significant in the short-run. Also they are significant at the 5% level. Furthermore the effect of precipitation on the exports revenues from cocoa in the long-run is meaningful for the cocoa world supply.

Table4: Results of the short-run relationship on the ECM

Variables	Coefficients	Standard error	T ratio
D[LOG (ODA)]	-0.013	0.0405	0.744
D[LOG(ODA(-1))]	-0.106	0.0428	0.018**
D[(LOG(EX)]	0.138	0.1793	0.194
D[(LOG(P)]	0.138	0.0126	0.445
D[(LOG(PR)]	-0.026	0.1046	0.049**
ECM(-1)	-1.129	0.1312	0.000***

**** indicates significance at the 1% level, ** indicates significance at the 5% level*

In table 5, is illustrated the results for the long-run regression. With the exception of exchange rate, the variables are significant at the 5% and 1% level. Precipitation in the long-run will negatively affect cocoa exports by reducing exports at about 2.3 percent per annum and the result is significant at the 5% level.

Table5: Results of a long-run relationship

Variables	Coefficients	Standard error	T ratio
LOG(ODA)	0.119	0.0359	0.002**
LOG(PR)	-0.023	0.0648	0.045**
LOG(EX)	0.122	0.0110	0.180
LOG(P)	0.804	0.0896	0.000***
C	6.416	0.3699	0.000***

**** indicates significance at the 1% level, ** indicates significance at the 5% level*

Finally, the stability of the regression of the model implemented and CUSUM test is used to check if the model is stable or not. From the figure, the curve lies within the bounds of the two red lines, therefore the model is stable and at the 5% level significance.

Conclusion and discussions

The change in the precipitation may affect crop production. A thorough investigation in the cocoa industry is relevant therefore the long-run effect of climate change on the export revenues of cocoa is meaningful. An autoregressive Distributed lag is applied to investigate the long-run relationship between the determinants of climate change and cocoa export earnings for Cote d'Ivoire's cocoa industry. Export revenues of cocoa, precipitation, official development assistance, production and exchange rate are factors considered that can explain this relationship. The study utilizes a times series dataset covering a period from 1966-2011. Stationarity tests confirm that all the variables are non-stationary after their first differences. Thus, it is appropriate to apply the ARDL model, and the bounds test shows a long-run relationship among the variables. We find that precipitation may affect the exports revenue of cocoa in the Ivorian economy. The finding matches with the Jones and Olken (2010) study that supports the conclusion stipulating adverse effects of precipitation on agricultural exports in developing countries.

Given that the Ivorian agricultural sector in general and the cocoa sector, in particular, contribute significantly to the national output of the economy, analyzing the immediate and long-term impact of a change in commodity outputs like cocoa through export revenue is necessary. The need to take the climatic changes into consideration is because of the result of erratic rainfalls in the cocoa cultivating regions in Cote d'Ivoire. The nature of the young cocoa trees, the varying temperatures and the level of top soil erosion also have a significant effect on the total yield. Authorities must implement policies in two stages. In the short run, results indicate that the decline in cocoa output per annum is faster. This decrease shows that within the next few years, the monetary amount or revenue collections will drop regularly. What authorities need to do is to incentivize production by subsidizing producers with fertilizers, and pesticides to boost production. Improve production facilities like farm to market roads, increase the minimum guaranteed price of cocoa exports at at least 65% of the international selling price. In the long run, the decline is slower. Diversification of agricultural products from cocoa into palm oil, rubber, and other soft commodity products like cashew and cotton. This strategy will be able to help the Ivorian economy to absorb a possible shock from the commodity markets and maintain a comfortable lead and steady stream of revenues from its internationally traded commodities.

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