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Does Climate Change Have Real Negative Impact on Economic Growth in Poor Countries? Evidence from Cote d’Ivoire (Ivory Coast)

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Abstract
The objective of this paper is to determine the impact of climate change on Cote d’Ivoire’s economic performance via per capita gross domestic product (GDP) growth, change in agricultural value added, and change in the country’s cereal yield. The data ranged from 1960 to 2016. An autoregressive distributed lag (ARDL) model is used to investigate the long run dynamics between climate variables (precipitation and temperature) and the country’s per capita GDP, agricultural value added as % of GDP, and cereal yield. We found that climate change has not significantly impacted the economic performance of the country. However, precipitation has been found to have positively and significantly influenced the country’s cereal yield and agricultural value added contribution to GDP at large, and thus there is no need to worry more than it is necessary.

Keywords: Climate change; Economic performance; Cointegration; Bounds tests.

1. INTRODUCTION
On December 2015, Parties to the United Nations Framework Convention on Climate Change (UNFCCC) gathered in Paris, France, to deliberate on the faith of our planet given concerns that global warming is undermining our livelihood and that actions should be taken before it is too late. Indeed, according to the World Health Organization, more than 140,000 people are dying per year as a direct result of climate change (Harris and Jones, 2017). Batten (2018) cited a survey of experimental studies conducted by Dell, Jones, and Olken (2014) that led to the conclusion that each degree greater than 25°C is associated to a productivity loss in various cognitive tasks of approximately 2%. Moreover, extreme temperatures could lead to negative health effects and increase the mortality and morbidity rates (Fankhauser and Tol, 2005). In the same vein, global warming could also cause mass migration and increase poverty, inequality, crime, and social unrest (Dell et al., 2014).

The results of the Paris deliberations led to the adoption of what is now known as the Paris Agreement. Among the key features of the Paris Agreement is the establishment of a global warming goal set to less than 2°C on preindustrial averages with efforts to limit the temperature increase to 1.5°C (Art. 2.1.a), and it defines a universal legal framework to strengthen the global response to the threat of climate change (The Paris Agreement, 2015—Art.2).

Although this agreement may seem ambitious, doing nothing could be catastrophic given that according to Reyer et al. (2017) warming in 2016 has reached 1.1°C compared to preindustrial (1800–1900) average.

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Several scholars (Dell et al., 2014) have empirically investigated the impacts of climate change on economic output worldwide (in the Americas, Europe, and Asia) but only few studies are focused on Africa in general and Cote d’Ivoire in particular. This impact on economic output could be via temperature’s impact on conflict and mortality especially in developing countries as argued by Curriero et al. (2002), Deschênes and Moretti (2009), Deschênes and Greenstone (2012), and Miguel, Satyanath, and Sergenti (2004). Adiku et al. (2015) also argued that the increased warming and shifts in rainfall patterns associated with climate change would adversely affect the agricultural growth in West Africa. This is worrisome because agriculture contributes between 40% and 60% of gross domestic product (GDP) in the region and is dominated by smallholder farmers. Knowing that global temperatures in particular are expected to increase over the next century and that developing countries are to suffer most from global warming if nothing is done (Dell, Jones, and Olken, 2012), it has become critical to understand and provide additional evidence on the relationship between climate change and economic growth so as to assess its possible impacts and call on policy makers for action.

In line with that mentioned earlier, the primary objective of this paper is to analyze the impact of climate change in Cote d’Ivoire. The specific objectives are as follows: (1) to determine the impact of climate change (temperature, precipitation) on the country’s economic growth rate, (2) to determine the impact of climate change (temperature, precipitation) on the country’s agricultural value added, and (3) determine the impact of climate change (temperature, precipitation) on the country’s cereal yield.

The remainder of the paper is organized as follows: Stylized facts on the trends of temperatures and precipitations are presented together with cereal yield, per capita GDP growth, and trend of economically active population (Section II). Section III reviews selected literature, Section IV presents the method of analysis and data to be used for the study, Section V presents the empirical results and discussions, while Section VI concludes the paper.

2. STYLIZED FACTS

One of the climate variables that is widely used is precipitation measured in millimeter of rain fall. In general, it is trivial that precipitation affects crop production and agricultural performance ceteris paribus. In addition, it impacts a country’s economic performance. In Figure 1, we look at the trend of precipitation together with that of cereal yield and see how they evolved over time. From Figure 1, we observe an upward sloping trend for cereal yield whereas precipitation has a slight downward sloping trend. The precipitation trend exhibits ups and downs throughout the period of interest. The country registered an average precipitation

![Figure 1. Trend of Precipitation (in mm) and Cereal Yield per Hectare in Cote d'Ivoire from 1960 to 2016.](source: World Development Indicators and World Meteorological Organization.)
of 1,276 mm with a minimum of 917 mm and a maximum of 1,708 mm. The graphical representation does not exhibit any link between the country's cereal yield and the level of precipitation. This is confirmed by a very low correlation coefficient that is not statistically significant (see Table 1A).

Different from Figure 1, Figure 2 shows how agricultural value added and precipitation evolved together over the period ranging from 1960 to 2016. We observe that both variables are downward sloping. They are positively correlated with a correlation coefficient of 0.241 that is significant at the 10% probability level. We then look at the trends of per capita GDP and precipitation (Figure 3). Here, we observe no clear pattern between the two variables. The correlation coefficient between these two variables is \(-0.142\), and it is not statistically significant (see Table 1A in the appendix).

**Figure 2. Trend of Annual Precipitation (in mm) and Agricultural Value Added in Cote d'Ivoire from 1960 to 2016.**

![Figure 2](source: World Development Indicators and World Meteorological Organization.)

**Figure 3. Trend of Annual Precipitation (in mm) and per Capita GDP in Cote d'Ivoire from 1960 to 2016.**

![Figure 3](source: World Development Indicators and World Meteorological Organization.)
We then looked at the temperature variable and observed how it has evolved over time. We first compare the trend of temperature to that of cereal yield (Figure 4). We observe that both variables are upward sloping and are thus correlated. The correlation coefficient is 0.526 and is significant at 1% probability level. The country registered an average temperature of 26.33°C over the period of interest with a low temperature of 25.45°C in 1976 and a high temperature of 27.06°C in 1998. Thus, the temperature in the country has alternated from high to low but within 25.45°C and 27°C. The variation of the country's temperature around its mean level is approximately 0.33°C. This national reading of temperature could hide extreme temperatures in some regions of the country. The positive correlation observed between temperature and cereal yield will be investigated further in the empirical analysis.

![Figure 4: Trend of Average Annual Temperatures (in °C) and Cereal Yield per Hectare in Cote d'Ivoire from 1960 to 2016.]

Source: World Development Indicators and World Meteorological Organization.

![Figure 5: Trend of Average Annual Temperatures (in °C) and Agricultural Value Added (% of GDP) in Cote d'Ivoire from 1960 to 2016.]

Source: World Development Indicators and World Meteorological Organization.
We move to look at how the trend of temperature compares to that of the country’s agricultural value added (Figure 5). Here, we observe two phases. The first one goes from 1960 to 1992, where we can see similar trends between temperature and agricultural value added. But from 1992 onward we observe a divergence of trend. Indeed, temperature is upward sloping, whereas agricultural value added is downward sloping. The correlation coefficient is \(-0.194\), and it is not statistically significant, which tells us that the decline in the agricultural value added contribution to GDP is not due to the rising temperature in the country.

In Figure 6, we look at the trend of temperature in line with that of the country’s per capita GDP. We observe that they do not have a similar trend. The correlation coefficient calculated is negative \((-0.591\) and statistically significant. Hence, the rising temperature has an adverse effect on the country’s economic performance. This will be investigated further in the empirical analysis section. The point of divergence started in 1986. Let us recall that the years 1983, 1984 were years of drought in the country. Temperature reached its highest point in over 10 years (1971–1983). We can see that from 1986 the country’s temperature kept increasing although not in a linear manner.

3. LITERATURE REVIEW

The literature on the climate-economy nexus is quiet diverse. Three types of outcomes are obtained from the literature. The first type found positive impact of climate variables on Economic output (Zilberman et al., 2004; Deschênes and Greenstone, 2007). The second (in majority) found negative relationship between climate variables and economic performance see Dell, Jones, and Olken (2008); Serdeczny et al. (2017); Akram (2012); Abidoye and Oduchola (2015); Mearns, Katz, and Schneider (1984); Moriondo, Giannakopoulos, and Bindi (2011); and García-León (2015). The last type combines studies that found both positive and negative impacts of climate variables on economic performance (Colacito, Hoffmann, and Phan, 2014; Zilberman et al., 2004). Agriculture has taken a large portion of this research (Adams et al., 1990; Mendelsohn, Dinar, and Sanghi, 2001; Deschênes and Greenstone, 2007; Guiteras, 2009; Fazal et al., 2013), and it is followed by ocean fisheries, fresh water access, migration tourism, etc. Let us look at studies that found positive impacts of climate on economic output.

3.1 Climate Change and Economic Output: A Positive Relationship

Deschênes and Greenstone (2007) measured the economic impact of climate change on US agricultural land by estimating the effect of random year-to-year variation in temperature and precipitation on agricultural profits. They found climate change to increase annual profits by 4%.
Zilberman et al. (2004), in a paper on “The Economics of Climate Change in Agriculture,” presented a conceptual framework of the impact of climate change on agriculture. They assumed that climate change results in a fertilization effect and a shift of agroecological conditions away from the equator toward the poles. The shift was likely to reduce yield because of reduced acreage, whereas the fertilization effect will increase yield. The aggregate effect depends on whichever of the two dominates.

3.2. Climate Change and Economic Output: A Negative Relationship
Dell et al. (2008) using annual variation in temperature and precipitation over 50 years examined the impact of climatic changes on economic activity throughout the world. They found that, first, higher temperatures substantially reduce economic growth in poor countries but have little effect in rich countries. Second, higher temperatures appear to reduce growth rates in poor countries, rather than just the level of output. Third, higher temperatures have wide-ranging effects in poor nations, reducing agricultural output.

Dell et al. (2012) used panel’s distributed lag structure to inform whether temperature affects aggregate economic activity in developing countries. They concluded that the increase in temperature correlates with a slowing of economic growth in developing economies but has no significant correlation in developed countries. They also documented that in poor countries, a 1°C increase in temperature in a given year reduces economic growth by approximately 1.3 percentage points in the same year, with agriculture, industry, and political instability as significant channels.

Serdeczny et al. (2017) in their paper on climate change impacts in Sub-Saharan Africa argued that the repercussions of climate change will be felt in various ways throughout both natural and human systems. They project a warming trend for the region, particularly in the inland subtropics that renders particularly vulnerable the rain-fed agricultural systems on which the livelihoods of a large proportion of the region’s population depend.

Lee, Villaruel, and Gaspar (2016), in study titled “Effects of Temperature Shocks on Economic Growth and Welfare in Asia,” using the Burke, Hsiang, and Miguel (2015) framework, examined the nonlinear response effect of economic growth to historic temperature and precipitation fluctuations. They confirmed a significant negative effect of rising temperature on agricultural production and industrial production.

Akram (2012), in a study to investigate whether climate change is hindering economic growth of Asian economies and using data ranging from 1972 to 2009 with a growth model incorporating temperature and precipitation as proxies for climate change in a panel setting, found that economic growth is negatively affected by changes in temperature, precipitation, and population growth. His results also indicate that agriculture is the most vulnerable sector to climate change.

Akram and Gulzar (2013) investigated climate change on economic growth in Pakistan using data ranging from 1973 to 2010 and temperature as proxy for climate change found that temperature has a negative and significant relationship with GDP and productivity in agriculture, manufacturing, and services sectors. However, severity of these negative impacts was higher in agriculture in comparison with manufacturing and services.

Ali (2012) conducted a study titled “Climate Change and Economic Growth in a Rain-fed Economy like Ethiopia.” Using cointegration analysis he found that both inter-annual and within-annual rainfall variations have negative effect on growth and that variability in rainfall has a long-term growth-drag effect through changes in its amplitude and frequency.

Abidoye and Oodusola (2015), in a study titled “Climate Change and Economic Growth in Africa: An Econometric Analysis,” using annual data for 34 countries from 1961 to 2009, found a negative impact of climate change on economic growth. The climate variable used is temperature. Their results reveal that a 1°C increase in temperature reduces GDP growth by 0.67 percentage point.

Nyangena (2016) explored the influence of weather change on the economic performance in Kenya. Using time series data ranging from 1964 to 2013 in a Vector Error Correction Model setting found that total rainfall had a negative relationship with gross domestic product while change in temperature indicated a positive relationship.

Adiku et al. (2015) found that the effects of climate change on yields relative to baseline climates were generally negative for cereal crops (i.e., millet and maize). They also cited studies by Mearns et al. (1984) and Moriondo et al. (2011) that found negative effect of temperature on crop yield. These studies described temperature as having the most adverse effect on crop yield among all weather parameters. Indeed, this is
so because certain stages of crop growth are particularly sensitive to temperature change. Increased temperature greater than certain thresholds, for majority of crops, can result in significant yield loss during the reproductive stage, through its effect on grain-filling, grain numbers and even sterility. It also exerts stress on the crop through high evapotranspiration and energy demands that otherwise would result in crop production but are instead used to manage the stress (Adiku et al., 2015).

García-León (2015), in his paper titled “Weather and Income: Lessons from the Main European Regions,” making use of a detailed weather and economic dataset covering the main regions of the five largest economies in the Euro area, found that global warming negatively affects, although in a modest manner, all regions within well-developed countries in the long term.

3.3. Climate Change and Economic Output: Both Positive and Negative Relationships

Colacito et al. (2014), in a study titled “Temperatures and Growth: A Panel Analysis of the U.S.,” provided empirical evidence that temperature affects economic growth in the United States. Their results revealed that (i) rising Summer temperatures depress growth, and (ii) rising Fall temperatures increase economic growth. Given that Summer temperatures are expected to increase at a faster pace relative to that of Fall temperatures, rising temperatures can decrease the growth rate of US GDP by as much as one third, thus resulting in large welfare losses.

The study by Zilberman et al. (2004) cited earlier is also an indication of how climate change can impact output. In this case, shift in agroecological conditions reduces agricultural growth, whereas the fertilization effect of climate change will increase yield.

Burke et al. (2015) analyzed the relationship between historical temperature fluctuations and macroeconomic growth. They found that, different from past studies, aggregate macroeconomic productivity is nonlinear, with productivity peaking at an annual average temperature of 13°C and declining strongly at higher temperatures. For cooler countries, warming will lead to an economic boom. Thus, given the presence of nonlinearity, climate change has a positive impact up to a threshold and shifts to a negative impact on economic output.

In addition, some studies try to dedramatize the impact of climate change on economic growth. Indeed, Mendelsohn et al. (2001), for instance, examined whether a country’s stage of development affects its climate sensitivity. They found that increasing development reduces climate sensitivity. Moreover, Mendelsohn (2009) in a paper on climate change and economic growth argued that the descriptions of the long-term consequences of climate change in the literature have given the impression that the climate impacts from greenhouse gases threaten long-term economic growth. However, the impact of climate change on the global economy is likely to be quite small over the next 50 years.

It results from the previous brief review of the selected literature that there is no consensus in terms of the effect (level and magnitude) of climate change on a country’s economic growth. It is argued in part of the literature that in developed countries, although exposed, they have the means to mitigate its effect and thus climate change impact is modest. Different from developed countries, poor countries are set to suffer the most because they lack resources to mitigate the possible negative effects of climate change. It is also found instances where climate change has both positive and negative impacts in developing countries. The impact depends on the agroecological conditions of the countries considered. This should be considered when analyzing the impact of climate change in panel data setting for West Africa (our next research work). There is no empirical evidence, to the best of our knowledge, provided for Cote d’Ivoire. This study intends to fill this gap.

4. METHOD(S)

The data to be used for this study is a time series and cover the period ranging from 1960 to 2016. Table 1 provides a brief description of the data and variables used for this study. The nonclimate variables are obtained from the World Development Indicators of the World Bank (2017). The climate variables are from Harris and Jones (2017). All the variables were transformed into logarithm. Thus, lngdpk, is the natural logarithm of gdpk, and so on. Given the time series nature of the data, it is critical to investigate its time series characteristics. This entails determining whether the variables to be analyzed are stationary or not. This is
performed using the traditional unit root test, that is, the Augmented Dickey Fuller (ADF) Unit Root Test and the Philip Perron (PP) Unit Root Test. This is important, because a regression of nonstationary variables on other nonstationary variables produce what is known as spurious regression.

The characteristics of the data via the unit root test show that the climate variables are stationary, that is, I(0), whereas the other three variables are stationary after first differencing, that is, I(1). The unit root test results are presented in Table 2.

In line with the previous results, we cannot use the traditional Granger and Johansen approached to investigate any long run relationship (cointegration). Indeed, the nonclimate variables are all I(1), that is, they stationary after first difference. The climate variables are all I(0), which means that they are stationary in levels. The appropriate approach therefore is to use the Bounds test proposed by Peseran, Shin, and Smith (2001 and 2004) to investigate any long run relationship.

### Table 1. Brief Description of the Data and Variables Used.

| Name of variable | Data source/Time period (1960–2016) | Comment |
|------------------|--------------------------------------|---------|
| $gdpk_t$         | WDI                                  | GDP per capita in constant 2010 US dollars |
| $agvat$          | WDI                                  | Agricultural value added as % of GDP |
| $ceryldt$        | WDI                                  | Cereal yield in kilogram per hectare |
| $lnvt_t$         | WDI                                  | Gross fixed capita formation as % of GDP |
| $Pop64_t$        | WDI                                  | Population aged 15–64 as % of total population |
| $Temp_t$         |                                      | Country level annual temperature in °C |
| $Precip_t$       |                                      | Country level annual precipitation millimeter of rainfall |

### Table 2. Results of Unit Root Tests.

| Test using ADF | Test using Philip Perron |
|----------------|--------------------------|
| Level          | 1st Diff.                | Level          | 1st Diff.                |
| $lngdpk_t$     | −1.284                   | −3.393*       | −1.529                   | −5.288*       |
| (0.636)        | (0.011)                  | (0.519)       | (0.000)                  |
| $lnagvat$      | −2.470                   | −7.416*       | −2.468                   | −7.417*       |
| (0.123)        | (0.000)                  | (0.124)       | (0.000)                  |
| $lnervyldt$    | −0.969                   | −11.330*      | −0.657                   | −11.829*      |
| (0.764)        | (0.000)                  | (0.858)       | (0.000)                  |
| $lnprecip_t$   | −7.138*                  | −7.138*       | −7.138*                  | −7.138*       |
| (0.000)        | (0.000)                  | (0.000)       | (0.000)                  |
| $lntemp_t$     | −4.529*                  | −4.519*       | −4.519*                  | −4.519*       |
| (0.000)        | (0.000)                  | (0.000)       | (0.000)                  |
| $lninvt$       | −1.408                   | −4.424*       | −1.687                   | −6.113*       |
| (0.578)        | (0.000)                  | (0.437)       | (0.000)                  |
| $lnpop64_t$    | −0.913                   | −2.156*       | −1.361                   | −2.725***     |
| (0.783)        | (0.018)                  | (0.601)       | (0.070)                  |

Author's calculation.
For this purpose, we formulate our model in a way that shows both the short run and long run dynamics. The autoregressive distributed lag (ARDL) model allows us to do this. The generalized ARDL\((p,q)\) model is as follows:

\[
Y_t = \alpha + \sum_{i=0}^{p} \delta_i Y_{t-i} + \sum_{i=0}^{q} \beta_j X_{t-i} + \varepsilon_t
\]

where \(Y_t\) is the endogenous variable, \(X_t\) represents the explanatory variables that are all allowed to be \(I(0)\) or \(I(1)\), \(\alpha\) is the constant, \(\delta\) and \(\beta\) are parameters to be estimated, and \(p\) and \(q\) are optimal lag orders. In this paper, we use the Akaike information criterion (AIC) to determine the optimal lag that provides us the unrestricted error correction model (Pesaran et al., 2001 called it conditional ECM) or put differently, conditional ARDL\((p,q)\) presented below:

\[
\begin{align*}
\Delta \text{lnagp}_t &= \delta_0 + \delta_1 \text{lnagp}_{t-1} + \delta_2 \text{lnprecip}_{t-1} + \delta_3 \text{Intemp}_{t-1} + \delta_4 \text{lnceryld}_{t-1} + \delta_5 \text{nagva}_{t-1} + \varepsilon_{1t} \\
\Delta \text{lnagv}_t &= \delta_0 + \delta_1 \text{lnagv}_{t-1} + \delta_2 \text{lnprecip}_{t-1} + \delta_3 \text{Intemp}_{t-1} + \delta_4 \text{lnceryld}_{t-1} + \delta_5 \text{nagva}_{t-1} + \varepsilon_{2t} \\
\Delta \text{lnceryl}_t &= \delta_0 + \delta_1 \text{lnceryl}_{t-1} + \delta_2 \text{lnprecip}_{t-1} + \delta_3 \text{Intemp}_{t-1} + \delta_4 \text{lnceryld}_{t-1} + \delta_5 \text{nagva}_{t-1} + \varepsilon_{3t}
\end{align*}
\]

The disturbance terms are such that, \(\varepsilon_{1t} : N\left(0, \sigma_1^2\right); \varepsilon_{2t} : N\left(0, \sigma_2^2\right)\) and \(\varepsilon_{3t} : N\left(0, \sigma_3^2\right)\). The disturbance terms are uncorrelated.

The Bounds test is equivalent to testing the following hypotheses:

\[
\begin{cases}
H_0 : \delta_u = \delta_v = \delta_w = 0 \\
H_1 : \delta_u = \delta_v = \delta_w = 0
\end{cases}
\]

The null hypothesis \(H_0\) tests the absence of a long run equilibrium relationship between the dependent variable and the explanatory variables. The statistics underlying this hypothesis test is the familiar Wald or \(F\)-statistics in a Generalized Dicker Fuller-type regression used to test the significance of lagged levels of variables under consideration in an unrestricted equilibrium error correction regression (Pesaran et al., 1999). Thus, if we accept \(H_0\), we can conclude that there is no long run relationship between the variables and that they are not cointegrated. However, if we reject the null hypothesis, then we conclude that there is a long run relationship between the variables. A key assumption in the ARDL Bounds Testing methodology of Peseran et al. (2001) is that the error terms in the previous equations be serially independent, that is, no autocorrelation. Once this condition is satisfied, we need to ensure that the model is dynamically stable.

It is important to understand the fact that the asymptotic distribution of both Wald and \(F\)-statistics is nonstandard under the null hypothesis of no long run relationship irrespective of whether the variables are \(I(0)\), \(I(1)\), or mutually cointegrated. However, Pesaran et al. (2001) have provided asymptotic critical values bounds for all classifications of the regressors into \(I(1)\) and/or \(I(0)\). Thus, if the computed \(F\)-statistics fall below the lower bound, then we accept the null hypothesis of no cointegration. In such situation, we
proceed to estimate the short run dynamics using Ordinary Least Squares (OLS) regression technic. If the \( F \)-statistics are greater than the upper bound, then we reject the null hypothesis and conclude that there exists a long run relationship between the variables. When this is the case, estimation of the ARDL model provides us with both the long run (levels equation) and short run dynamics (difference equation). If the \( F \)-statistics fall between the bounds, then the test is inconclusive. In this case, knowledge of the cointegration rank of the forcing variables (explanatory variables) is required to proceed further (Peseran et al., 1999).

In addition to the \( F \)-test performed earlier, we can also perform a “Bounds \( t \)-test” to cross-check the results. The test is as follows:

\[
\begin{align*}
H_{01} : \delta_i = 0 & \quad \text{vs} \quad H_{i} : \delta_i < 0 \\
H_{02} : \delta_i = 0 & \quad \text{vs} \quad H_{2} : \delta_i < 0 \\
H_{03} : \delta_i = 0 & \quad \text{vs} \quad H_{3} : \delta_i < 0
\end{align*}
\] (6)

Here also, the null hypothesis \( H_0 \) tests the absence of a long run equilibrium relationship between the dependent variable and the explanatory variables. If the \( t \)-statistics are greater than the I(0) bound tabulated by Peseran et al. (2001, pp. 303-304) and Kripfganz and Schneider (2018, pp. 30-33), then accept the null hypothesis and conclude that there is no cointegration between the variables. If the \( t \)-statistics are less than the I(1) bound, then reject the null hypothesis and conclude that there is long run relationship between the variables. Here again, if the \( t \)-statistics fall between the two bounds, the test is inconclusive. All computations were performed using the statistical software Stata 14.2.

5. RESULTS AND DISCUSSION

5.1. Empirical Results

In this section, we present the empirical results. We start with the descriptive statistics presented in Table 3. The country’s average GDP per capita stood at US$ 1,547 in constant 2010 US dollars. The highest level reached was US$ 2,391 in 1978 couple of years before the country entered a severe recession in 1980. The contribution of agricultural value added stood on average at 28.6%. It ranges from 20.9% (2013) to 47.9% in 1960. The country’s cereal yield stood at 1,226 kg/ha on average and ranged from 624 kg/ha (1960) to 2,270 kg/ha in 2010 right before the civil war in 2011. It reduced to 1,882 kg/ha in 2011. Capital formation in the country has been minimal and stood at an average of 15.9% over the period of analysis with a low level of 8.2% of GDP in 2003 and a high level of 29.66% of GDP in 1978 (period categorized as the Ivorian Miracle).

The investigation of the time series characteristics of the data shows that with the exception of the climate variables, that is, precipitation (\( \text{lnprecipt} \)) and temperature (\( \text{lntempt} \)), that are stationary, that is, I(0), the remaining variables are all I(1), that is, first difference stationary. These results were obtained using both

| Variable | Obs | Mean   | Std. Dev. | Min    | Max    |
|----------|-----|--------|-----------|--------|--------|
| Gdpk     | 57  | 1,547.043 | 330.909  | 1,138.660 | 2,391.920 |
| Agva     | 57  | 28.617  | 6.758     | 20.980  | 47.910 |
| Ceryld   | 57  | 1,226.240 | 495.375  | 624.200 | 2,270.500 |
| gfcf     | 57  | 15.997  | 5.668     | 8.250   | 29.660 |
| pop1564  | 57  | 52.926  | 0.813     | 51.710  | 54.620 |
| precip   | 57  | 1,276.100 | 147.829  | 917.033 | 1,708.070 |
| temp     | 57  | 26.331  | 0.331     | 25.450  | 27.060 |
the Augmented Dickey Fuller and Philip Perron Unit Roots tests (Table 2). This clearly indicates a case for applying the ARDL Bounds Testing to investigate any long run relationship. Given that none of the variables of interest is I(2), we determine the number of lags \((p,q)\), where \(p\) is the number of lags for the dependent variable and \(q\) is the number of lags for the independent variables. As indicated earlier, we used the AIC to determine the number of lags for each of the model to be considered before conducting the Bounds test.

Let us recall that we have three (03) models (three dependent variables). The first model (Equation 2) deals with the impact of the climate variables on the country’s economic growth (Gross Domestic Product per capita). The second model looks at the impact of the climate variables on agricultural productivity measured as agricultural value added as a percentage of GDP (Equation 3). The third model deals with the impact of climate variables on the country’s cereal yield (Equation 4). For each Equation (2, 3, and 4), we consider different variants ranging from a restricted model with only the climate variables (Model 1) to a full model with all the explanatory variables (Model 3). Model 2 is the restricted model augmented with the capital formation variable \((\ln invt)\).

Using the AIC, the lags order for Model 1 is \((1, 0, 0)\), that of Model 2 is \((1, 0, 0, 1)\), and that of Model 3 is \((2, 0, 0, 1, 2)\). The Bounds test results indicate that no long run relationship between the variables in both the restricted and the unrestricted Model (1 and 3). In the case of Model 1, the \(F\)-statistic falls between the bounds making the test inconclusive; however, the \(t\)-statistic has a value \((-2.547)\) greater than the lower bound for I(0), which is \(-2.860\). We therefore accept the null hypothesis and conclude that the variables are not cointegrated and hence, no long run relationship. Here, both the \(F\)-statistic and \(t\)-statistic provide support to the null hypothesis of no long run relationship. For these two models, we estimate the short run dynamics that is equivalent to running OLS on first difference. The results are presented in the Table 5. The Bounds test on Model 2 provides different results. Let us recall that in Model 2 we augmented the restricted model with only the capital formation variable \((\ln invt)\). The \(F\)-statistic (5.414) is greater than the upper bound critical value for I(1), that is, 4.35. We therefore reject the null hypothesis and conclude that there is a long run relationship. We estimate both the level Model and the short run dynamics. The results are presented in Table 5.

Let us now consider Equation 3 (with agricultural value added as the dependent variable). We also consider three models as mentioned earlier (Table 6). Using AIC, the lags order for Model 1 is \((1, 0, 0)\), and that of Model 2 is \((1, 0, 0, 3)\), and that of Model 3 is \((1, 0, 0, 1, 0)\). The Bounds tests yield the following results: For Models 1 and 3, the null hypothesis of no long run relationship cannot be rejected. Indeed, although the \(F\)-statistics are inconclusive, the \(t\)-statistics are higher than the critical values at the 5% probability levels. Hence, we accept the null hypothesis of no cointegration and we estimate the short run dynamics. Here also,
Table 5. Results of the ARDL Estimation of the Impact of Climate on Economic Growth in Cote d’Ivoire (Equation 2).

|          | Model 1 ARDL(1,0,0) | Model 2 ARDL(1,0,1) | Model 3 ARDL(2,0,0,1,2) |
|----------|---------------------|---------------------|------------------------|
|          | Constant 2.453      | 2.331               | 6.657                  |
|          | (0.302)              | (0.221)             | (0.186)                |
| $ECT_{t-1}$ | -0.138*             |                     |                        |
|          | (0.002)              |                     |                        |
| $lnpret$  | 0.413               |                     |                        |
|          | (0.346)              |                     |                        |
| $Intemp_t$ | -4.271              |                     |                        |
|          | (0.241)              |                     |                        |
| $lninv_{t}$ | 0.572*              |                     |                        |
|          | (0.000)              |                     |                        |
|          | Long run dynamics   |                     |                        |
|          | Short run dynamics  |                     |                        |
| $\Delta lngdpk_{t-1}$ | 0.936*            |                     | 0.978*                 |
|          | (0.000)              |                     | (0.000)                |
| $\Delta lngdpk_{t-2}$ |                     | -0.188              | (0.209)                |
|          |                      |                     |                        |
| $\Delta lnpre_{t}$  | 0.103               | 0.057               |                        |
|          | (0.096)              | (0.296)             |                        |
| $\Delta Intemp_t$   | -0.830              | -0.386              | (0.480)                |
|          | (0.215)              | (0.480)             |                        |
| $\Delta lninv_{t}$  | 0.102*              | 0.182*              |                        |
|          | (0.026)              | (0.000)             |                        |
| $\Delta lninv_{t-1}$ |                     | -0.092              | (0.067)                |
|          |                      |                     |                        |
| $\Delta lnpop64_t$  |                     | -8.693*             | (0.022)                |
|          |                      |                     |                        |
| $\Delta lnpop64_{t-1}$ | 14.516*            |                     |                        |
|          |                      |                     | (0.028)                |
| $\Delta lnpop64_{t-2}$ |                     | -6.959              | (0.051)                |
|          |                      |                     |                        |
| Adj R-squared | 0.938               | 0.391               | 0.961                  |
| F(3, 52)  | $278.790^*$          | $8.070^*$           | $149.84^*$            |
| F(5,47)  | (0.000)              | (0.000)             | (0.000)               |
| Breusch-Godfrey LM test for absence of autocorrelation |                     |                     |                        |
| chi2 (1) | 3.798 (0.051)        | 0.015 (0.903)       | 0.056 (0.813)          |
| White's test for Ho: homoscedasticity |                     |                     |                        |
| chi2(9)  | 9.680 (0.377)        | df(20) 15.770 (0.731) | df(54) 55.000 (0.436) |
| See graph for stability test |                     |                     |                        |

For each model, we tested for the absence of serial correlation as well as homoscedasticity. In both cases, the null hypothesis of no autocorrelation and homoscedasticity could not be rejected.
Table 6. Bounds Tests for Cointegration in the Agricultural Productivity Model.

|                | Model 1 ARDL(1,0,0) | Model 2 ARDL(1,0,0,3) | Model 3 ARDL(1,0,0,1,0) |
|----------------|----------------------|-----------------------|------------------------|
| \( H_0 \rightarrow \) no levels relationship |                      |                       |                        |
| F-stat         | 4.293                | 4.895                 | 3.015                  |
| Crit val at 5% | [l(0) l(1)]          | [l(0) l(1)]           | [l(0) l(1)]            |
| \( k = 2 \)    | [3.79  4.85]         | \( k = 3 \)           | [3.23  4.35]           |
| \( k = 4 \)    | [2.86  4.01]         |                       |                        |
| Test is unconclusive |                       | Reject H0 if F > F-val for l(1) | Test is unconclusive |
| t-stat         | -2.547               | -3.307                | -2.429                 |
| Crit val at 5% | [l(0) l(1)]          | [l(0) l(1)]           | [l(0) l(1)]            |
| \( k = 2 \)    | [-2.86  -3.53]       | \( k = 3 \)           | [-2.86  -3.78]         |
| \( k = 4 \)    | [-2.86  -3.99]       |                       |                        |
| Accept H0 if t > t-val for l(0) |                       | Test is unconclusive | Accept H0 if t > t-val for l(0) |

Table 7. Results of the ARDL Estimation of the Impacts of Climate on Agricultural Productivity.

|                | Model 1 ARDL(1,0,0) | Model 2 ARDL(1,0,0,3) | Model 3 ARDL(1,0,0,1,0) |
|----------------|----------------------|-----------------------|------------------------|
|                |                      |                       |                        |
| Long run dynamics |                     |                       |                        |
| Constant       | -2.227 (0.400)       | -3.713 (0.206)        | -1.026 (0.760)         |
| \( ECT_{t-1} \) |                      | -0.174* (0.002)       |                        |
| \( \ln ppre_t \) | 1.296* (0.037)       |                      |                        |
| \( \ln temp_t \) | 4.539 (0.419)        |                      |                        |
| \( \ln invt_t \) | 0.166 (0.376)        |                      |                        |
| Short run dynamics |                     |                       |                        |
| \( \Delta \ln agvat_{t-1} \) | 0.880* (0.000)       | 0.886* (0.000)        |                        |
| \( \Delta \ln ppre_t \) | 0.202* (0.025)       | 0.210* (0.026)        |                        |
| \( \Delta \ln temp_t \) | 0.357 (0.661)        | 1.013 (0.291)         |                        |
| \( \Delta \ln invt_t \) | -0.148* (0.043)      | -0.127 (0.085)        |                        |
| \( \Delta \ln invt_{t-1} \) | -0.058 (0.430)       | 0.133 (0.081)         |                        |
| \( \Delta \ln invt_{t-2} \) | -0.152* (0.046)      |                        |                        |
| \( \Delta \ln pop64_t \) |                      | -0.867 (0.259)        |                        |

(Continued)
Model 2 behaves the same way as in the Economic Growth Equation, that is, the $F$-statistic is higher than the upper bound for I(1) at the 5% probability level. Hence, we reject the null hypothesis of no cointegration and conclude that there is a long run relationship between the variables and estimate both the level model together with the short run dynamics. Estimation results are presented in Table 7.

Let us consider now Equation 4 (with cereal yield as dependent variable). Here also, we consider three models as mentioned earlier. Using AIC, the lags order for Model 1 is $(2, 0, 1)$, and that of Model 2 is $(2, 0, 1, 0)$ and that of Model 3 is $(2, 0, 1, 0, 1)$. The Bounds tests (Table 8) yield the following results: The $F$-statistic is unconclusive in all the three specifications. However, the $t$-statistics are all greater than the lower bounds for I(0). Hence, we accept the null hypothesis of long run relationship between the variables. We therefore move on to estimate the short run dynamics. Results are presented in Table 9.

### 5.2. Climate Change and Economic Growth

Based on the stability test provided by the graph below, we consider the unrestricted Model (3) and found no long run relationship between climate change and economic growth as measured by per capita GDP growth. Although the two climate variables did not impact significantly the economic performance of the country, we noticed that precipitation is positively associated with economic growth whereas temperature is negatively associated with the country’s growth. The negative association between temperature and growth is in line with previous work by Abidoye and Odusola (2015); Dell et al. (2008, 2012). It is rather the

| Table 8. Bounds Test for Cointegration in Cereal Yield’s Model. |
|------------------------|------------------------|------------------------|
| **Model 1** ARDL(2,0,1) | **Model 2** ARDL(2,0,1,0) | **Model 3** ARDL(2,0,1,0,1) |
| $H_0 \rightarrow$ No levels relationship | $H_0 \rightarrow$ No levels relationship | $H_0 \rightarrow$ No levels relationship |
| **F-stat** | **F-stat** | **F-stat** |
| $[I(0) \ I(1)]$ | $[I(0) \ I(1)]$ | $[I(0) \ I(1)]$ |
| $[3.79 \ 4.85]$ | $[3.23 \ 4.35]$ | $[2.86 \ 4.01]$ |
| $k = 2$ | $k = 3$ | $k = 4$ |
| Test is unconclusive | Test is unconclusive | Test is unconclusive |
| **t-stat** | **t-stat** | **t-stat** |
| $[I(0) \ I(1)]$ | $[I(0) \ I(1)]$ | $[I(0) \ I(1)]$ |
| $[-2.86 \ -3.99]$ | $[-2.86 \ -3.99]$ | $[-2.86 \ -3.99]$ |
| $k = 2$ | $k = 3$ | $k = 4$ |
| Accept H0 if $t > t$-Val. for I(0) | Accept H0 if $t > t$-Val. for I(0) | Accept H0 if $t > t$-Val. for I(0) |
| $t$-Val. for I(0) | $t$-Val. for I(0) | $t$-Val. for I(0) |

Author’s calculation (* significance at 5% probability level).
level of Gross Fixed Capital Formation (Investment) that has positively and significantly affected the country’s economic growth. This calls for a revisit of the country’s investment policy. As indicated earlier in this paper, the highest level of investment stood at 29.66% of GDP and this was several decades back in 1978 during what was categorized as the Ivorian miracle. The current level of investment that stood at 20.46% is still less than its 1978 level. More productive investments are needed if the country is to ascend to emerging country status.

The other variable of interest is the growth of the economically active population. It has a significantly negative impact on the country’s economic performance. This is of no surprise given the high level of unemployment in the country. To mitigate the negative impact of this variable on the country’s economic performance, it is important that the country’s employment policy be revisited to ensure that skills are built to address present and future challenges of the country and sectors such as agriculture, construction,

| Table 9. Results of the ARDL Estimation of the Impact of Climate on Cereal Yield in Cote d’Ivoire. |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Model 1 ARDL(2,0,1)                          | Model 2 ARDL(2,0,1,0)                          | Model 3 ARDL(2,0,1,0,1)                        |
| **Short run dynamics**                        | **Short run dynamics**                        | **Short run dynamics**                        |
| **Constant**                                  | **Constant**                                  | **Constant**                                  |
| $-12.207^*$                                   | $-11.180^*$                                   | $-14.506^*$                                   |
| (0.009)                                       | (0.025)                                       | (0.014)                                       |
| $\Delta \text{lncre}_t$                       | $\Delta \text{lncre}_t$                       | $\Delta \text{lncre}_t$                       |
| $0.529^*$                                     | $0.522^*$                                     | $0.471^*$                                     |
| (0.000)                                       | (0.000)                                       | (0.000)                                       |
| $\Delta \text{lncre}_t$                       | $\Delta \text{lncre}_t$                       | $\Delta \text{lncre}_t$                       |
| $0.385^*$                                     | $0.386^*$                                     | $0.383^*$                                     |
| (0.001)                                       | (0.001)                                       | (0.002)                                       |
| $\Delta \text{lnpre}_t$                      | $\Delta \text{lnpre}_t$                      | $\Delta \text{lnpre}_t$                      |
| $0.243^*$                                     | $0.257^*$                                     | $0.238^*$                                     |
| (0.027)                                       | (0.024)                                       | (0.050)                                       |
| $\Delta \text{lnpre}_t$                      | $\Delta \text{lnpre}_t$                      | $\Delta \text{lnpre}_t$                      |
| $0.026$                                       | $-0.107$                                      | $-0.376$                                      |
| (0.982)                                       | (0.928)                                       | (0.751)                                       |
| $\Delta \text{lnpre}_t$                      | $\Delta \text{lnpre}_t$                      | $\Delta \text{lnpre}_t$                      |
| $3.368^*$                                     | $3.191^*$                                     | $2.764^*$                                     |
| (0.005)                                       | (0.010)                                       | (0.027)                                       |
| $\Delta \text{lninvt}_t$                     | $\Delta \text{lninvt}_t$                     | $\Delta \text{lninvt}_t$                     |
| $-0.023$                                      | $-0.107$                                      | $-0.376$                                      |
| (0.572)                                       | (0.928)                                       | (0.751)                                       |
| $\Delta \text{lnpop64}_t$                    | $\Delta \text{lnpop64}_t$                    | $\Delta \text{lnpop64}_t$                    |
| $8.157$                                       | $6.609$                                       | $6.609$                                       |
| (0.133)                                       | (0.195)                                       | (0.195)                                       |
| $F(5, 49) \rightarrow 188.820^*$ (0.000)      | $F(6,48) \rightarrow 155.240^*$ (0.000)       | $F(8,45) \rightarrow 116.600^*$ (0.000)       |
| $\text{Adj R-squared}$                       | $\text{Adj R-squared}$                       | $\text{Adj R-squared}$                       |
| 0.946                                         | 0.945                                         | 0.946                                         |
| Breusch-Godfrey LM test for absence of autocorrelation
| $\text{chi}^2(1)$ (0.993)                    | $\text{chi}^2(1)$ (0.986)                    | $\text{chi}^2(1)$ (0.993)                    |
| White’s test for Ho: homoscedasticity
| $\text{chi}^2(20)$ (0.718)                   | $\text{df}(27)$ (0.863)                      | $\text{df}(44)$ (0.501)                      |

Author’s calculations.
health, security, and education are on the forefront. Here, we emphasize education because it is key for skill building, and it should therefore be lifelong in nature.

This graph shows that the estimated model is stable (Model 3).

5.3. Climate Change and Agricultural Value Added
Here, in line with the stability test (see graph below) we consider Model 2. The Bounds test indicate a long run relationship between the climate variables and agricultural value added. Indeed, the error correction term is negative ($-0.174$) and highly significant. It confirms the cointegration between the variables. The results also indicate that there is long run causality running from precipitation to agricultural value added. Indeed, precipitation has a positive (1.296) and significant impact on agricultural value added. Different from precipitation, temperature does not have a significant impact on agricultural value added. When we consider the short run dynamics, we observe that the investment variable has a negative impact on agricultural value added. This is understandable, especially if investments are done outside the agricultural sector to enable the processing of agricultural products. In such an instance, the contribution of agricultural value added to GDP will decline while that of the Industrial sector will increase. The tests of the null hypotheses of no autocorrelation ($P$-value of 0.175) and homoscedasticity ($P$-value of 0.533) could not be rejected.

This graph shows that the estimated model is stable (Model 2).

5.4. Climate Change and Cereal Yield
For this model, although the tests for the null hypotheses of no serial correlation and homoscedasticity could not be rejected for all the three equations, the results for the stability tests were not satisfactory (see the three graphs that represent Models 1, 2, and 3, respectively). We therefore considered the restricted
The objective of this paper was to determine the impact of climate change on Cote d’Ivoire’s economic performance via per capita GDP growth, change in agricultural value added and change in the country’s cereal yield. The Analysis was conducted using data ranging from 1960 to 2016. The climate variables considered in this analysis were precipitation (millimeter of rainfall) and temperature (degree Celsius). We found that climate change has so far not significantly impacted the economic performance of the country. Climate change (precipitation) has been found so far to have positively and significantly influenced the country’s cereal yield and agricultural value added contribution to GDP at large, and thus there is no need to worry more than it is necessary. Notwithstanding the previous results, it would be important to investigate whether there is a threshold level of precipitation and temperature beyond which the country’s economic performance and cereal yield will be at risk.

6. CONCLUSION

The objective of this paper was to determine the impact of climate change on Cote d’Ivoire’s economic performance via per capita GDP growth, change in agricultural value added and change in the country’s cereal yield. The Analysis was conducted using data ranging from 1960 to 2016. The climate variables considered in this analysis were precipitation (millimeter of rainfall) and temperature (degree Celsius). We found that climate change has so far not significantly impacted the economic performance of the country. Climate change (precipitation) has been found so far to have positively and significantly influenced the country’s cereal yield and agricultural value added contribution to GDP at large, and thus there is no need to worry more than it is necessary. Notwithstanding the previous results, it would be important to investigate whether there is a threshold level of precipitation and temperature beyond which the country’s economic performance and cereal yield will be at risk.

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## Table 1A. Pairwise Correlation between the Variables of Interest.

|       | Ingdpk | Inagva | Inceryld | Inpre | Intemp | Ininvl | Inpop64 |
|-------|--------|--------|----------|-------|--------|--------|---------|
| Ingdpk  | 1.000  |        |          |       |        |        |         |
| Inagva  | 0.007  | 1.000  |          |       |        |        |         |
| Inceryld | -0.606* | -0.660* | 1.000    |       |        |        |         |
| Inpre   | -0.142 (0.291) | 0.241** (0.071) | 0.096 (0.480) | 1.000 |        |        |         |
| Intemp  | -0.591* (0.000) | -0.194 (0.149) | 0.536* (0.000) | 0.191 (0.155) | 1.000 |        |         |
| Ininvl  | 0.701* (0.000) | 0.217 (0.104) | -0.548* (0.000) | 0.113 (0.404) | -0.425* (0.001) | 1.000 |         |
| Inpop64 | -0.674* (0.000) | 0.115 (0.393) | 0.476* (0.000) | 0.345* (0.009) | 0.401* (0.002) | -0.061 (0.651) | 1.000 |

Author’s calculation.