The influence of climate change on Uganda's international trade flows: Evidence from weather anomalies

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Abstract

Unquestionably, climate scientists divulge that the Earth's climate will change at a unique rate over the 21st century, thus envisioning global warming. Succinctly, it is postulated that African countries largely reliant on the agricultural sector seem to be predominantly vulnerable to this phenomenon. Hastening climatic changes are noted to influence migration (hence urbanisation in agricultural dependant economies), natural adversities like floods, pest and disease infestations, droughts, mass movements, and a rise in sea level among others. Some research has evaluated the impact of climate change on migration and economic growth but no empirical study is has been come across examining the influence of climate change (*proxied by temperature and precipitation anomalies*) on international trade.

This study therefore examines the impact of climate change on Uganda's trade flows with six major trade partners. While using weather anomalies (temperature and precipitation) to proxy climate change, the study explores panel data methods basing on secondary data traversing from 1970 to 2000. The study uses the Feasible Generalised Least Squares (FGLS) estimator to run an augmented gravity model. Empirical results reveal that climate change exhibits negative effects on Uganda's bilateral trade flows, particularly through its influence on the agricultural sector and through temperature fluctuations in the export markets. Conclusively, climate change has deterring effects on Uganda's trade flows. Policy wise, it is prudent to invest in advanced agricultural technologies, such as developing tropical crop varieties and animal breeds that are tolerant to extreme climatic conditions. This is very vital in ensuring sustainable bilateral trade flows.

Keywords: Agriculture, climate change, FGLS, gravity model, International trade, sub-Saharan Africa, panel data

JEL Codes: C33, N77, Q17, Q54

1. BACKGROUND

Uganda is a landlocked country, where Agriculture remains the back bone of the economy. According to the International Federation of Organic Agriculture Movement (IFOAM) and Research Institute of Organic Agriculture (FiBL) (2006), Uganda has the most developed sector of certified organic producers, utilising about 1% of total arable land within the country. Notably, a majority of farmers rely on organic agriculture and are not certified, thus Uganda is rated to have the lowest agro-chemical usage in Africa (ACODE, 2006). Despite the declining trend (estimated at 29 percent between 1988 and 2009) in contributing to total Gross Domestic Product (GDP), the agricultural sector accounts for about 80% of employment and 90% of the country's foreign exchange earnings (NPA, 2010; UBOS, 2010). The declining trend in the contribution of this fundamental sector is attributed to climate change related factors (drought, pests and diseases out breaks) among others (NPA, 2010).

Agricultural exports are broadly classified as either, Traditional Exports (TEs) or Non- Traditional Exports (NTEs). Traditional exports are those agricultural produce which have been grown with a purpose of earning an income and these are coffee, tea, cotton and tobacco. On other hand, NTEs are all those agricultural produce that were originally produced for the purpose of providing food although of recent, they are also exported to generate foreign currency. These NTEs include flowers, fish and fish products, fruits and vegetables, among others (UBOS, 2007). Going without say, Uganda's exports are predominantly unprocessed agricultural commodities with coffee being the key foreign exchange earner. The major export products include coffee, cotton, dried bananas, paw paws, pineapples, passion fruits, chillies, ginger, sesame cut flowers, fish and fish products, hides and skins, among others.

2. Problem statement

Generally, there is still rather scanty empirical literature evaluating the effects of climate change on international trade. Predominantly, such literature epicentres on various measures to proxy climate change. These proxies include; greenhouse gas emissions (Wang, 2012; Folfas *et al*., 2011; Kee *et al.*, 2010; Aichele and Felbermayrz, 2010; Kim and Koo, 2010), environmental permits (Folfas *et al*., 2011), regulations (Kee *et al.*, 2010), directives, emissions trading certificates, tradable renewable energy certificates, and weather-related disasters. For instance, World Bank (2008) used carbon/ energy tax and energy efficiency standards to study the impact of climate change on the exports of OECD countries. More often than not, such studies have ignored the fact that climate is more complex due to the interdependency of climatic and weather-related natural factors. Moreover, climate change proxies like carbon tax and greenhouse gas emissions used in capturing climate change effects among developed (industrious) countries are less reliable, especially in the context of developing regions like East Africa due to the fact that the composition of their exports are skewed towards agriculture (Hoekman and Nicita, 2011; Bineau and Montalbano, 2011), which is directly influenced by consequences of weather related natural factors such as temperature, rainfall, cloud cover and humidity among other climatic factors.

Specifically, Melo and Mathys (2010) mention that measuring Greenhouse gas in the agriculture sector is very is difficult, thus complicating the actual quantification of the effects of climate changes on agricultural trade. According to Bineau and Montalbano (2011), this is compelling developing countries to substitute the old energy models so as to catch-up with industrialization. Notably, given that this transition is unprecedented and requires heavy initial investment costs, United Nations (UN) (2009) affirms that this is one of the major obstacles in curbing climate change effects. World Bank (2008) reveals that most of these climate change measures do not directly target any particular product, but rather focus on the method by which greenhouse gases may implicitly be related to production. Therefore, climate change related policies based on these measures may have implications for trade (Bineau and Montalbano, 2011), especially on agricultural commodities. Better measures should be based on temperature, precipitation, humidity and other weather related factors since according to Deschenes and Greenstone (2007) these are direct inputs in the agricultural sector. Putting this into consideration, the most plausible way to make a good assessment of climate change effects on international agricultural trade architecture is to use a redefined proxy for climate change, which can easily and directly be linked to agriculture. The above mentioned approaches used to proxy climate change effects on trade hardly take into account of the agricultural based economies. Thus, policies based on these climate change measures may be misleading. In order to enhance informed policy decisions in an agriculture based economy like Uganda, this paper aims at evaluating the effects of climate change proxied by temperature and precipitation anomalies on international trade flows.

3. The link between climate change, agriculture and trade

Along the supply chain, climate change directly affects international trade at the production phase through its effects on the productivity of agricultural farms. As shall be seen in this section, climate change influences a number of aspects which in turn curtail agricultural production, hence hampering trade in general. Precisely, climate change may disrupt trade flows for instance through a sudden disaster like floods, which may destroy crops and other facilities or through some gradual changes to an ecosystem which also incapacitate production. According to Chalise and Ghimire (2013), the significance of temperature alone as a climatic factor across all sectors accounts for over 90 percent in influencing productivity, followed by rainfall, among others. In agriculture for instance, both temperature and precipitation are key climatic factors in influencing crop yield (Alexandrov and Hoogenboom, 2001). According to Drine (2011) climate change is attributable to the low agricultural productivity given the fact that uncertainty inhibits innovation and imitation. In addition, it is argued that uncertainty about agricultural production is bound to upsurge as severe climate events like droughts and floods are anticipated to be more recurrent and to cause more catastrophes. Therefore, given the pervasive risky environmental effects on farming practices and farm performance, the increasing uncertainty may perhaps dishearten farmers from upgrading production technology, thus affecting productivity.

As a stylized fact, Marchiori *et al.* (2010), World Bank (2010), IPCC (2007), and, Deschenes and Greenstone (2007) unequivocally confess that whereas climate change has less detrimental effects on the manufacturing industry, the agricultural sector is exceedingly vulnerable to this phenomenon. This is more likely to be exhibited among the many poor economies banking on agrarian activities. Notably, the direct effects may be exhibited in form of rural-urban migration (Marchiori *et al*., 2010), which culminates into reallocation of the scarce labour force from the agricultural sector in rural areas to the non-agricultural sectors in urban areas. Although the populace may have a genuine cause to change from one sector to another, Collier *et al.*(2008) and Barrios *et al.* (2006) argue that this reallocation of labour is simply a mechanism of adapting to climate change. As a result, this is likely to transform into reduced production on farms thereby causing deficits in agricultural produce.

Given that many Sub Sahara African (SSA) countries mainly rely on small-scale, subsistence, rain-fed agriculture, i.e. farmers produce mainly for home consumption and only sell in instances of surpluses; reduced farm production due to rural-urban migrations will inevitably curtail trade in agricultural commodities. The effect of rural-urban migration (reallocation of scarce labour) is actually more eminent in communities characterised of non-functioning rural markets, like Uganda. In instances where rural markets are functional, households affected by rural-urban migration would be in position to hire labour to substitute for what would be availed by out-migrants on the farm. Alternatively, such households would also borrow money for agro-inputs to boost production. However, in an eventuality that labour and credit markets are not functional, this affects farm production.

According to Barrios *et al.* (2006), erraticism in precipitation has an extensive assortment of commercial repercussions in the developing economies given that it is the main source of water. For instance, water shortages are highly associated with detrimental effects such as hunger and in extreme cases, death. In Africa *per se*, precipitation variability is certainly very important because of its significance in the agricultural sector. In most SSA, agriculture greatly depends on God given rainfall to provide crops with water. Unlike in developed economies, a very small proportion of arable land is irrigated in SSA economies. Notably, the productivity of various crops has been shown to reduce due to variability in temperature and precipitation (FAO, 2001; Kumar *et al.*, 2004; Parry *et al*., 2004; Schlenker and Lobell, 2010; Tao *et al*., 2003; 2008; Sivakumar *et al*., 2005; Xiong *et al*., 2007). In Uganda for example, annual crops like maize and beans are by far more susceptible to climate change than perennial crops like tea, coffee and bananas. Maize is generally most sensitive to drought (extreme temperature), while beans tend to be most sensitive to excessive rainfall (UNDP and BCPR, 2013).

The high vulnerability of annual crops is due to the fact that intense events can hastily wipe out the annual crop, leaving farmers with no harvest while perennial crops might often survive but with lower yields or reduced quality. Thus, drastic changes in climatic conditions can impact on the length of a crop's growing period, and therefore yields, among other aspects. McCandless *et al.* (2012) used an ecophysiological crop model called the Decision Support System for Agrotechnology Transfer (DSSAT) to study the impacts of temperature and precipitation on the growth and yield of maize and bean crops in Rakai, and Kapchorwa districts of Uganda. Their empirical results project that bean production in Kapchorwa district will decline by approximately 6 percent while maize production may experience an 8 to 10 percent decrease by 2050. With regard to Uganda's major cash crop (Coffee), Simonett (1989) shows that a 2°C increase in temperature would lead to a significant fall in the production of Robusta coffee in the country.

Temperature as a climatic factor also presents a number of effects on trade through various avenues. According to Dell *et al.* (2008), temperature can also affect agriculture through its effects on investments or institutions that influence productivity growth. These in the long run affect a country's economic activities, where trade is inclusive. For instance, higher temperatures are renowned to lead to conflict and political insecurity in poor countries (Dell *et al.*, 2008; Field, 1992; Jacob *et al*., 2007; Miguel *et al*. 2004; Boyanowsky, 1999) and during such periods of unrest, there is limited agricultural production. Dello *et al.*, (2008) goes further to show that a 1^0C increase in temperature in developing economies leads to approximately 2.37 percent loss in the growth of agricultural output. This decline then affects the total GDP, which is a key determinant for trade as per the gravity model theory. Furthermore, it is affirmed that for every increase in 100mm of annual precipitation, there is an accompanying 0.24 percent increase in agricultural output growth in developing countries and a 0.14 percentage rise in agricultural output in developed countries.

4. Climate change proxies

For over a decade, the climate change phenomenon has attracted increasing attention at various levels. Ardently, Bettin and Nicolli (2012) exemplify the special conference sessions that have been devoted to deliberate on this topic, *viz*: "Migration, Globalization and the Environment Migration, Globalization and the Environment" and "Environmentally Induced Migration" were held during the "International Society for Environmental Epidemiology (ISEE) Conference in 2004" and "European Association of Environmental and Resource Economists (EAERE) conference in 2011", respectively. Institutionally, a number of reports quantifying the economic effects of climate change have been produced by the World Bank, the Centre for Environmental Economics and Policy in Africa (CEEPA) among other institutions.

In the international trade domain *per se*, scholars like Wang (2012), Folfas *et al*. (2011), Kee *et al.* (2010), Aichele and Felbermayrz (2010), Kim and Koo (2010), Kee *et al.* (2010), and World Bank (2008) have used one or a combination of: greenhouse gas emissions, environmental permits, environmental regulations and permits, emission trading certificates and tradable renewable energy certificates to proxy climate change. However, as earlier mentioned these measures are limited by the inability to appropriately reflect issues pertaining agriculture grounded economies, thus being apt for industrious economies. More often than not, the commonly used measure of climate change is expressed in terms of the total number of people dead or affected by a natural disaster. This approach has been plausibly used by many scholars (*see* Alexeev et al., 2011; Drabo and Mbaye, 2011; Reuveny and Moore, 2009; Rauveny, 2007). Despite the fact that there exists a set of 23 aggregate environmental indexes used to proxy climate change, Bettin and Nicolli (2012) put it that no consensus has been reached about the utmost apt indicators of climate change to be fitted in models. In addition, most of these indexes were described to be inappropriate in explaining the trend of climate change at a global level. Worse still, these environmental indicators were grossly limited by their incapability to cover many countries and their failure to distinguish local effects of climate change. Ardently, IPCC (2007) contends that climate change manifests itself in a number of ways, for examples, through temperature and precipitation fluctuations, rise in sea level and extreme events, thus climate change proxies may not be limited to being mutually inclusive.

Due to the above mentioned limitations, the trend in empirical research has oriented towards the use meteorological data, from which weather anomalies used to proxy climate change can be generated. Various studies (Barrios *et al.*, 2010; Deschenes and Greenstone, 2007; and Kurukulasuriya *et al.*, 2006) among the many that have used meteorological data, employ different data sources, like the TYN CY 1.11 dataset provided by the Tyndall Centre for Climate Change Research, Parameter-Elevation Regressions on Independent Slopes Model (PRISM) dataset which was developed by the Spatial Climate Analysis Service at Oregon State University for the National Oceanic and Atmospheric Administration (Available online at: http://www.ocs.orst.edu/prism/docs/przfact.html). Other meteorological data sources include the Africa Rainfall and Temperature Evaluation System, created by the Climate Prediction Centre of the U.S. National Oceanic and Atmospheric Administration and the U.S. Department of Defence satellites, where data are measured by a Special Sensor Microwave Imager (SSMI), to mention but a few.

According to Bettin and Nicolli (2012), the use of meteorological data is advantageous over environmental indexes because of two crucial reasons. (*i*) It gives a better reflection of the real effects of climate change, and (*ii*) such data are available in long time series for a majority of the economies internationally. Advantageously, Barrios *et al*. (2010), Nicholson (1986) and Munoz-Diaz and Rodrigo (2004) mention that the use of anomalies over year by year variation reduces the potential scale effects and takes into account the likelihood of higher variance in the data for the more arid countries.

5. Empirical applications of weather anomalies as a proxy for climate change

Given that no scholarly work has been come across examining the effects of climate change (hereafter referred to as "weather anomalies") on international trade, the literature review in this section is therefore limited to studies in other sectors that proxy climate change as anomalies in temperature and precipitation. Notably, a handful of papers have evaluated the effects of climate change on various economic aspects while employing anomalies, expressed as the deviation in temperature and rainfall from the long term means. For instance, while basing on annual, cross-country panel data for sub-Saharan Africa, Marchiori *et al*. (2010) used temperature and rainfall anomalies to assess the effects of climate change on international migration. Study findings divulge that climate change influences the populace's decision to migrate from Sub-Saharan Africa. Succinctly, authors estimate that weather anomalies were liable for the migration of about 2.55 million people in Sub-Saharan Africa for over a period of 40 years. With the aim of ascertaining the role of climate change in the economic performance of Sub-Saharan countries, Barrios *et al*., (2006) used precipitation anomalies to proxy climate change. Findings disclose that anomalies in rainfall influence the urbanisation patterns in Sub-Saharan Africa through their effects on agriculture. Worthwhile to note, none of these studies laboured to address the effects of climate change on trade flows.

6. Analytical Model

Our specified model generally builds on the classic gravity flow model that has been over the years acknowledged to be the utmost authoritative tool in explaining bilateral trade flows (Anderson, 1979). This model, pioneered by Tinbergen (1962) and Pöyhönen (1963) originates from Newton's "Law of Universal Gravitation" proposed in 1687. It states that the attractive force between two objects *i* and *j* is a positive function of their respective masses (Y_i and Y_j) and a negative function of the distance (D_{ij}) between them.

Mathematically, this is expressed as;

$$X_{ij} = R * \left(\frac{Y_i^{\alpha} Y_j^{\beta}}{D_{ij}^{\gamma}} \right) \quad \text{...} \quad (1)$$

Where X_{ij} is the trade flow from origin *i* to destination *j*, Y_i and Y_j denote the economic mass of the exporting and importing country, respectively. D is the distance between the commercial centers of the two countries and Remoteness (R) replaces the gravitational constant, G. However, due to the multiplicative nature of the model, the stochastic log-linearised version of the basic gravity model can be expressed as stated in equation (2).

$$\ln X_{ij} = \alpha \ln Y_i + \beta \ln Y_j - \gamma \ln D_{ij} + \rho \ln R_j + \varepsilon_{ij} \quad \text{..} \quad (2)$$

Given the advancement in theory, the original gravity equation has been modified by augmenting it with extra variables during the 1980s and 90s.

Mathematically, our empirical specification follows the augmented version and it is expressed as:

$$\ln TDijt = \alpha ij + \beta_1 \ln UG\_gdp_{it} + \beta_2 \ln J\_gdp_{jt} + \beta_3 \ln Dij + \beta_4 \ln Agri\_gdp_{it} + \beta_5 \ln V_{it}$$
$$+ \beta_6 \Pr e\_DUg_{it} + \beta_7 Temp\_DUg_{it} + \beta_8 \ln Agri\_prep_{it} + \beta_9 \ln Agri\_tem_{it} + \beta_{10} Temp\_D_{jt}$$
$$+ \beta_{11} \Pr e\_D_{jt} + DUK + \varepsilon ij \quad \text{..} (3)$$

where ln denotes natural logarithms; TD_{ijt} is total bilateral trade (sum of exports and imports) between Uganda and her j th trading partner in year t in Billions of US Dollars; UG_gdp_{it} is Uganda's real GDP in year t in Billions of US Dollars; J_gdp_{jt} is real GDP of the j^{th} trading partner in year t in Billions of US Dollars; D_{ij} is distance between Kampala and her jth trading partner's commercial centre in Miles. $Agri\_gdp_{it}$ is used to capture the relevance of the agriculture sector in Uganda's economy. It is expressed as the proportion of GDP from agricultural sector to total GDP. Pre_DUg_{it} and $Temp\_DUg_{it}$ denote Uganda's precipitation and Temperature anomalies respectively in year t. $Agri\_tem_{it}$ and $Agri\_prep_{it}$ represent the interaction of the agriculture sector with temperature and precipitation respectively. V_{it} is real exchange rate volatility, while DUK is a dummy variable denoting the effect of colonial ties to Britain (=1, if both were colonised by Britain; and = 0 if otherwise).

7. Variables and Data sources

Temperature and precipitation anomalies at country level were computed following following Bettin and Nicolli (2012); Barrios *et al*. (2010), Marchiori *et al*. (2010); and Barrios *et al*. (2006) as expressed in the general formula below;

$$TA_{i,t} = \left[\frac{T_{i,t} - T_i}{SD_i} \right] \quad \ldots\ldots (4)$$

Where, $TA_{i,t}$ denote temperature anomaly, $T_{i,t}$ denote temperature of country *i* at time *t*, T_i denote long run country average temperature value, and SD_i denote the long-run standard deviation of country *i*. The same formula applies for computing precipitation anomalies, denoted as Pre.

These climatic variables are calculated by means of data from the TYN CY 1.11 database elaborated by Mitchell *et al*. (2004, 2005). This dataset comprises of nine (9) variables, *viz*: daily mean, minimum and maximum temperature (degrees Celsius); daily temperature range (degrees Celsius); frost day frequency (days); precipitation (millimetres); wet day frequency (days); vapour pressure (hectaPascals); and cloud cover (percentage). Meteorological observations were modelled on 0.5° latitude by 0.5° longitude grid that covers the world land surface (New *et al*., 1999, 2000). For transforming the gridded data into country-level mean values, each grid box was allocated to a single territory and the weighted mean calculated. Mitchell candidly notes that weights were chosen according to climatological reasons. In instances where data were insufficient to obtain a value, it was relaxed towards the 1961-1990 mean (Mitchell *et al*., 2002). This represents the long rung climatological mean to refer to (IPCC, 2007). This results into a dataset with country level climatological information from 1901 to 2000, flawlessly apt for econometric analyses. Basing on grounded effects of weather anomalies on the agricultural sector, these variables are expected to have a negative effect on international trade flows.

So as to control for the fact that climate change may influence international trade, predominantly in an agricultural sector based economy like Uganda, we also interdepend the agricultural sector variable with the measure of anomalies in precipitations and temperature (i.e. $Agri\_prep_{it}$ and $Agri\_tem_{it}$, respectively). The expected sign of the each coefficient is thus negative.

Real Gross Domestic Product (GDP) of the trading economies signifies both the productive and consumption capacity. Thus, it fundamentally defines trade flows between them. GDP is the foundation to proxy for the economic size of any economy; therefore it is ordinary that the GDP of an importing economy plays a significant part in influencing trade from exporting economies. Similarly, an exporting country's GDP supports in determining the productive capacity of that very country, *viz*: the amount of the goods and services that might be provided. According to the theoretical foundation of the gravity model, an exporting country's GDP is expected to stimulate trade flow of goods and services from that very country. Thus, an increase in real GDP of any two or more trading countries also increases trade flows. Hence, the coefficients of Real GDPs are expected to be positive. Real GDP at constant prices of 1990 were taken from the IFS (IMF, 1998; 2007) and from the United Nations Statistics Division Common Database. However, United Nations' GDP estimates were used because the figures were given in a uniform and an internationally recognised dollar currency unlike the IMF figures that were reported in the respective national currencies.

Distance (D_{ij}) is proxy used for the trade cost between countries. Distance is a trading resistance factor that represents trade barriers such as transportation costs, delivery time, cultural unfamiliarity and market access barriers. Among other factors, higher transportation costs reduce the volume of trade and increase information costs. Countries with short distance between each other are expected to trade more than those who are wide apart because of reduced transaction costs. Distance can also be used as a proxy for the risks associated with the quality of some of the goods and the cost of the personal contact between managers and customers. Generally, the coefficient of distance is expected to negatively influence the flow of trade between countries. Despite the cardinal "great circle" formula which estimates the earth's shape as a sphere and computes the minimum distance along the surface, distances were acquired using the geographical distance. Distance data are the air distances between the capital cities (Economic centres) of designated trade partners with reference from Kampala, Uganda. These data were taken from www.mapcrow.info/distance and www.worldatlas.com

This paper takes into account Real exchange rate volatility given that it can affect trade, both directly and indirectly. Direct effects can be through ambiguity and adjustment costs, while indirect effects can be attributable to its inspiration on the structure of output and investment and on government policy (Cote, 1994). The sign on the coefficient of Real exchange rate volatility is expected to be negative. Dummy for common colonial master (DUK) was also added to capture the influence of colonial masters on bilateral trade flows among the trading partners. Given that countries having common colonial masters tend to have common trade agreements, among other cultural similarities, this presents more trading opportunities, thus the expected sign of the estimated coefficients is positive. The significance of agriculture in Uganda's economy is expressed as the percentage of the overall GDP produced by the agricultural sector ($Agri\_gdp_{it}$) and data are obtained from the World Development Indicators. The expected sign of the coefficient is positive.

8. Empirical results

We determine the effect of weather anomalies on bilateral trade flows using the augmented gravity model. The specified model was run using the Feasible Generalised Least Squares (FGLS) estimator due to the fact that it takes into account of the heteroskedasticity of the error terms within panels and assumes that there is no auto correlation among the variables.

The results presented in Table 1 below generally divulge that all variables (other than trade partner J's precipitation anomaly (*prp_dj*); the contribution by Agricultural sector (*lnagri_gdp*); and Real Exchange rate volatility (*lnv*)) significantly influence Uganda's bilateral trade flows. Surprisingly, the contribution by Agricultural sector presents an unexpected negative relationship with bilateral trade flows.

Table 1: The influence of climate change on bilateral trade flows

Dependent Variable = natural log of Bilateral Trade Flows		
Variables	**Coefficient**	**p-value**
Constant	17.901 (2.338)	0.000
Uganda's Temperature anomaly (Temp_Dug)	5.367*** (2.042)	0.009
Uganda's Precipitation anomaly (*Pre_Dug*)	2.489** (1.064)	0.019
Interaction between Agricultural sector and temperature (*lnAgri_tem*)	-1.319*** (0.507)	0.009
Interaction between Agricultural sector and precipitation (*lnAgri_prep*)	-0.615** (0.265)	0.020
Trade partner J's temperature anomaly (*temp_Dj*)	-0.102** (0.047)	0.031
Trade partner J's precipitation anomaly (*prp_dj*)	-0.012 (0.043)	0.790
Uganda's real GDP (*lnUG_gdp*)	0.571** (0.301)	0.058
Real GDP of partner J (*lnJ_gdp*)	0.336*** (0.079)	0.000
Distance between economic centres (*lnD*)	-1.119*** (0.105)	0.000
Common colonial master (DUK)	1.458*** (0.105)	0.000
Contribution by Agricultural sector (*lnagri_gdp*)	- 0.225 (0.518)	0.664
Real Exchange rate volatility (*lnv*)	-0.053 (0.033)	0.111
N	217	
Wald $chi^2(12)$	484.28	
p-value $Chi^2(12)$	0.0000	

Note: ***, **, * denote statistical significance at the 1%, 5%, and 10% levels; in parentheses are standard errors

The variables of interest that proxy climate change are temperature and precipitation anomalies in both the exporting (Uganda) and importing countries, plus the interaction terms between the agriculture sector and the climate change variables ($lnAgri\_tem_{it}$ and $lnAgri\_prep_{it}$). Empirical results indicate that weather anomalies exhibit both positive and negative effects while the associated interaction terms with the agricultural sector divulge negative effects on Uganda's bilateral trade flows.

Findings reveal that a one percent (1%) change in Uganda's temperature and precipitation anomalies increases bilateral trade flows by about five percent (5%) and two percent (2%), respectively. The positive findings may be attributed to the fact that this study considered both imports and exports in totality. According to UBOS (2002), a majority of Uganda's imports are high valued non-agricultural products (*viz*, petroleum products and related materials, automobiles, Machinery, Telecommunications equipment and Pharmaceutical products). Scholars (Marchiori *et al*., 2010; World Bank, 2010; IPCC, 2007; Deschenes and Greenstone, 2007) opine that climate change has minimal detrimental effects on manufactured goods. Notably, their production, thus supply, does not necessarily depend on climatic factors like temperature and precipitation. In 2000 for example, the European Union bloc (from which most of Uganda's trade partners considered in this study come) assumed the largest share (20%) as the source of imports. Imports from this bloc were valued at US$213 million (UBOS, 2002). The positive influence of weather anomalies on Uganda's trade flows may as well be attributed to the Uganda's warm tropical climate.

Therefore, the warm climate coupled with the two rainfall seasons enhance trade in a wide spectrum of goods and services all year round without interruptions, as compared to other regions of the world that experience extreme temperate conditions like winter, which probably limits trade in certain products. Notably, anomalies in precipitation were observed to have a lower influence on Uganda's trade flows as compared to temperature anomalies. This unmatched effect on trade flows may be explained by the destructive nature of excessive precipitation on physical infrastructure, say through the washing away of roads and bridges, destruction of manufacturing and processing industries, land mass movements, floods and loss of lives. All these shortfalls associated with excessive precipitation culminate into increased barriers to trade since they impede easy and quick access to goods and services, thus increasing the cost of doing business. For instance, according to the Emergency Disasters Database (EM-DAT) (2013), floods that occurred in Uganda on the 14^{th} day of November 1997 led to economic damage costs estimated at a staggering one million US dollars.

On the other hand, anomalies in temperature and precipitation in the trading partner's countries were found to negatively affect Uganda's trade flows. For instance, a unit change in temperature and precipitation anomalies at the destination markets (trading partners) were found to deter Uganda's trade flows by approximately 0.1 and 0.01 percent, respectively. These results may be explained by the tendency of Uganda's key destination markets (*especially the Europe Union*) to favour its production calendar, by protecting the domestic producers within the EU market. This is based on production seasons, which move in tandem with the climatic seasons (winter, summer, spring and autumn), among other factors. Notably, Petriccione *et al.* (2011) posit that under the non-reciprocal Generalized System of Preferences (GSP) scheme, the European Union (EU) market categorises a majority of the agricultural commodities as either being sensitive or non sensitive, and then subjects them to a special entry price system.

This system uses two types of duties, *viz*: the ad-valorem duties and the specific duties. Intuitively, it is asserted that this approach is aimed at ensuring price stability and to prevent very cheap products on the European market. However, given that Uganda majorly exports unprocessed agricultural products, this mechanism acts as a disincentive in promoting trade in the EU market. Moreover, the EU market also alters tariff levels of some commodities, especially fruits and vegetables within a calendar year. More often than not, altering of tariffs arises during harvesting periods which coincide with the northern hemisphere winter season. For instance, Uganda Investment Authority (UIA) (2001) notes that the November to February harvesting period in Uganda coincides with the winter season in Europe, a period of peak demand for fresh fruits and vegetables. For instance, the GSP scheme only favours importation of Cucumber (fresh or chilled) into the EU market from 16 May up to 31

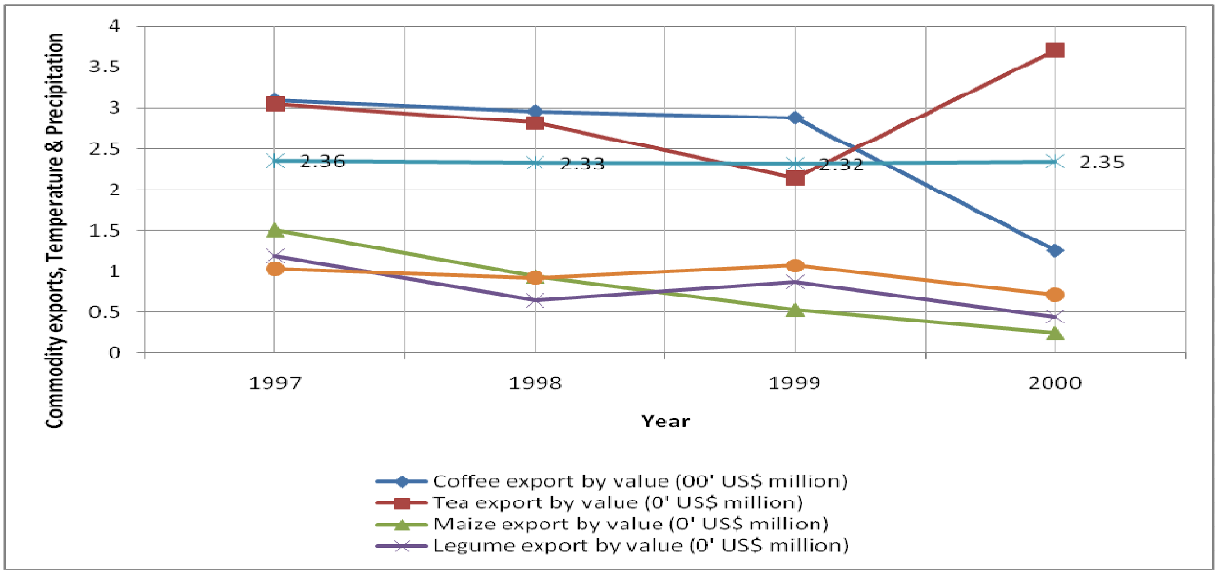
December. Other commodities whose exportation to the EU market is limited by the GSP scheme include Mandarins (0805 20), Plums (0809 40) and fresh Peaches (*nectarines inclusive*) (0809 30), among others (UNCTAD, 2008)

Despite the fact that Uganda's anomalies in temperature and precipitation do not individually affect total trade flows, they exhibit statistically significant negative effects on trade flows if interpretation in terms of how they influence the agricultural sector. For instance, the interaction term between temperature anomalies and the agriculture sector (*lnAgri_tem*) reveals that the effects of fluctuations in temperature on the agriculture sector have a depressing effect on Uganda's trade flows. Results show that a unit change in this interaction term leads to an estimated 1.32 decline in total trade flows. This finding may be attributed to the fact that Uganda's exports are majorly dominated by raw agricultural products, which are highly vulnerable to the weather vagaries (UBOS, 2002). For example, coffee is the leading traditional cash crop over the years and it contributed more than 30 percent to total export earnings in 2000 alone. Hence, perturbations during the production phase of this crop (among others) inevitably impacts on the yield, thereby reducing the economy's basket of tradable goods. This argument concurs with other scholars (McCandless *et al.*, 2012; Schlenker and Lobell, 2010; Tao *et al.*, 2008; 2003; Simonett, 1989) who succinctly acknowledge the grounded negative effects of increasing temperatures on a number of crops

Similarly, the interaction between precipitation anomalies and the agriculture sector shows that a unit change in this interaction term leads to about 0.62 decrease in Uganda's trade flows. This finding closely concurs with (Schlenker and Lobell, 2010; Tao *et al.*, 2008; Xiong *et al.*, 2007; Sivakumar *et al.*, 2005; Kumar *et al.*, 2004; Parry *et al.*, 2004;), since production directly determines the availability of produce to be traded. Food and Agricultural Organization (FAO) (2001) notes that fluctuations in rainfall patterns cause a decline in crop production. This negative relationship may further be due to the re-allocation of labour from the agricultural sector in rural areas to the industrial sector in urban centres through rural-urban migration (Marchiori *et al.*, 2010). According to statistics by the World Development Indicators (WDI) (2012), Uganda had over 0.45million emigrants in net terms over a period of five-years (1996-2000). This signifies a plausible amount and quality of labour lost, most likely due to the prolonged drought experienced in 1999. Notably, this is the only period during which the country observed emigration outweigh immigration during the 1990s. Worthwhile to note, during the 1986-1994 and 1991-95 periods, about 0.23 and 0.12 million immigrants (in net terms) were registered to have entered into the country.

Graph 1 below vividly provides the supporting evidence about negative nexus between some selected agricultural commodities and precipitation (*See Appendix 1 for weather anomalies for the entire study period, 1970-2000*).

Graph 1: Exports of selected agricultural commodities by value (US$), in relation to Temperature (0C) and Precipitation ('000 mm)



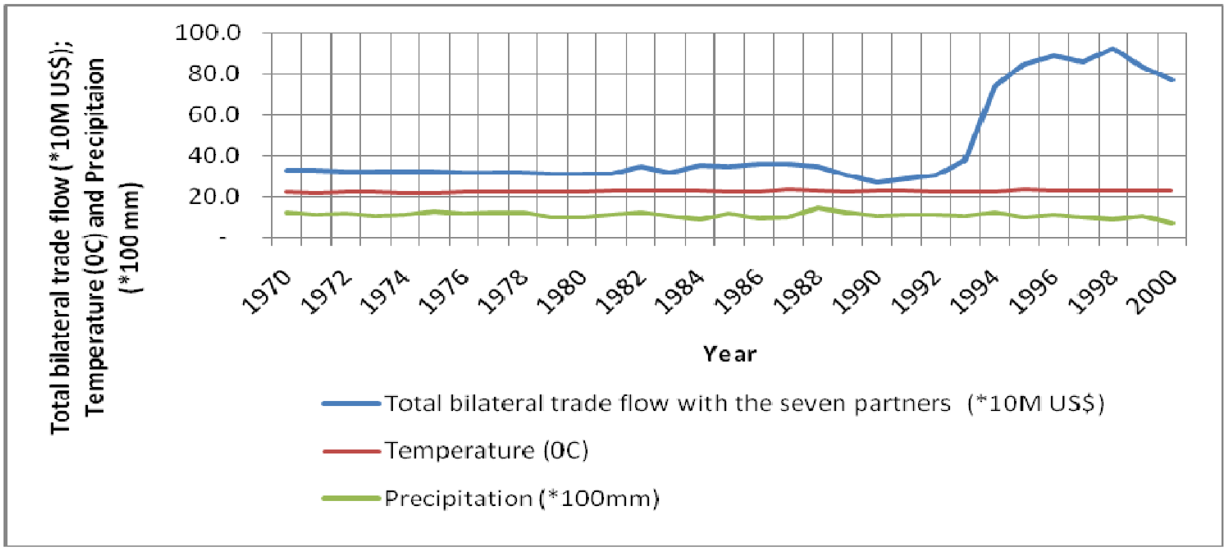
Source: UBOS statistics and TYN CY 1.11 database

With the exception of tea, a 33 percent drop in annual precipitation between 1999 and 2000 (from 1073.2mm to 715.5mm) lead to a 56.5% decline in coffee export earnings, while a 53.9% and a 49.1% decrease were registered in maize and legume export earnings, respectively. According to EM-DAT (2013), the associated economic damage costs due to the long drought that begun in 1998 but intensified in 1999 was estimated at 1.6 million US$ and by August 1999, about 700 thousand people had been severely affected.

On the contrary, the sharp increase in tea export earnings between 1999 and 2000 (*see* Graph 1), despite the hastening drop in precipitation may be well explained by Hanna (1971). Hanna argues that under permitting conditions, tea yields will greatly increase if there is accessible soil water and adequate solar energy. As evidently illustrated on the graph, it can be seen that temperature of 23^0C was within the recommended agronomic requirements for tea production to provide the desirable solar energy, hence the high yields that rendered availability of large quantities of tea to be exported. Moreover, the decline in precipitation was also within the optimum range conducive for tea production.

At an aggregated level, graph 2 below further affirms that fluctuations in precipitation and temperature indeed deter Uganda's bilateral trade flows. During the 1986-91 period, the monetary value of total bilateral trade flows with the seven partners considered in this study experience a 19.6 per cent declined from 360 to 289 million US dollars. This could be associated with an increase in annual temperature by 0.9 degrees Celcius during this period, coupled with recurrent precipitation fluctuations.

Graph 2: Uganda's total bilateral trade flows with the seven trade partners, in relation to temperature and precipitation



Source: UBOS statistics and TYN CY 1.11 database

The exponential increase in total exports after the early 1990s was due to the liberalisation of the economy. Despite the fact that climatic factors like precipitation continued to fluctuate, economic liberalisation boosted trade across a number of sectors.

9. Conclusions and Policy implications

This study aimed at ascertaining the influence of climate change on Uganda's international trade flows with six major trade partners, while using weather anomalies to proxy climate change. The study explores panel data methods based on secondary data traversing from 1970 to 2000 and it uses the Feasible Generalised Least Squares (FGLS) estimator to run an augmented gravity model. Empirical results showed that climatic variables (temperature and precipitation anomalies) have significant effects on Uganda's trade flows. Although Uganda's weather anomalies on their own seem not to deter trade flows, their influence on the agriculture sector significantly depresses international trade flows. This is attributable to the fact that Uganda's trade flows are majorly raw agricultural products, whose production solely relies on temperature and precipitation as factors of production. Fluctuations in temperature and precipitation in the destination markets also has a deterring effect on Uganda's trade flows. This observation may be due to the tendency of these markets (especially the Europe Union) to protect their domestic producers within the EU market by subjecting agricultural commodities to a special entry price system through the use of ad-valorem duties and the specific duties. The negative relationship between Uganda's trade flows and weather anomalies in destination markets is attributable to the EU's mechanism of altering tariff levels of some commodities, especially fruits and vegetables within a calendar year, especially during harvesting periods which coincide with the northern hemisphere winter season.

Given that both interaction terms between the agriculture sector and weather anomalies (temperature and precipitation) are significantly negative; this has policy implications for the government and the private sector to generously invest in advanced agricultural technologies. Such technologies may involve the developing of tropical crop varieties and animal breeds that can withstand extreme climatic conditions. Furthermore, well knowing that climate change is a trans-boundary problem that requires collective effort and that it cannot be tackled overnight, it is prudent for populace to embrace agro-processing technologies so as to contain problems associated with highly perishable agricultural produce. This will enable Uganda to diversify its products base, thereby refraining from the raw agricultural products that are subjected to special entry price system, and to penetrate into many more markets. This is very vital in ensuring sustainable bilateral trade flows.

10. Limitations and directions for future research

The empirical findings in this study are based on aggregate annual trade; hence results should be interpreted with caution. There is need to study specific commodities since different commodities have differing temperature and precipitation requirements.

Due to climatological data limitations, the study was grounded on historical data which may not adequately provide the true representation on Uganda's international trade flows to date. Therefore, there is need to extend this research by using recent climatological data.

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Appendix 1: Uganda's weather anomalies over the 1970 -2000 period