Climate Change and Macro Prices in Nigeria: A Nonlinear Analysis

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The study analyses the impacts of climate change on macro prices (food prices, interest rate, and exchange rate). Secondary data from 1960–2019 are used, and the nonlinear autoregressive distributed lag method is employed accordingly. The results reveal that there is a long-run relationship among the variables employed. In addition, asymmetry only exists between food prices and exchange rate in the short run while it only subsists for all macro prices, except interest rate as a dependent variable, in the long run. Also, the relative effects of climate change on macro prices grade food prices with the highest effect. In fact, the continual need for climate policies in both financial and real sectors to douse the effect of climate change on macro prices cannot be overemphasised. Therefore, this study recommends that the Nigerian government and policymakers should ratify and pursue policy initiatives and strategies based on both negative and positive changes in macro prices.

Key Words: asymmetry, climate change, macro prices, nonlinear ARDL
JEL Classification: E31, E43, F31, Q54

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Introduction

Literature is replete with the impact of climate change on food prices, owing to its implication for agricultural and manufacturing-sector productivity growth (Food and Agriculture Organisation of the United Nations 2016; 2019b; 2021; Foye and Benjamin 2021; Hendrix and Haggard 2015; Kreidenweis et al. 2016; Ogbuabor et al. 2020; Zhang et al. 2018). However, there is a paucity of literature on the relationship that exists between climate change and macro prices (food prices, and also isolated exchange and interest rates generally). This is because a general increase in food prices (food inflation) is one of the major channels to exchange rate volatility in an open economy, and interest rate has become topical in climate economics, as policymakers seek to stabilise the general price level by targeting inflation. In addition, studies on climate change and international trade have been able to establish that the former is critical in achieving the macroeconomic objective of exchange rate stabilisation (Lee et al. 2021; Mckibbin et al. 2017; Tol 2006). To sum up, the relationship between climate change and macro prices is intertwined with not only a dearth of studies on the exchange and interest rates aspects but also the fact that little or no attention has been given to it, and likewise the relative effects of climate change on the different macro prices in a study. This has inhibited policymakers in formulating and proffering adequate policy strategies and recommendations to reverse the consequences of climate change for macro prices. Therefore, this study seeks to analyse the extent to which climate change affects macro prices and also to determine the relative effects of climate change on macro prices in Nigeria. This is with the view to attending to the peculiarity of Nigeria, as one of the countries most vulnerable to climate change, and also for adequate policy initiatives, recommendations, and implementations.

Climate change (global warming) is a long-term change in weather patterns reflected as a sustained increase in the mean temperature of the earth over decades (Foye and Benjamin 2021; IPCC n.d.; NASA: Global Climate Change; Vital Signs of the Planet n.d.). This change could be anthropogenic (human induced) or biogeographical. However, research has unequivocally established that climate change is human induced (Foye 2018; IPCC n.d.; NASA: Global Climate Change; Vital Signs of the Planet n.d.). Examples of such human activities are the burning of fossil fuels like coal, oil and natural gas (through industrialisation, gas flaring, and urbanisation, among others) which results in the dominance and persistence of carbon dioxide (CO_2) among other greenhouse gases (GHGS, such as methane, nitrous oxide, and fluorinated gases) in the atmosphere (see United States Environmental Protection Agency n.d.a; n.d.c; Foye 2018). These gases remain in the atmosphere for decades to thousands of years, and long enough for the gases to become well mixed. This means that the amount that is in the atmosphere is approximately the same all over the world, regardless of the source/country of the emissions (United States Environmental Protection Agency n.d.c). This is why climate change is referred to as a global phenomenon which impairs lives and livelihoods. Therefore, at the last 26th Conference of Parties (COP), efforts were made to deliver on and keep to the Paris Agreement of a 1.5° Celsius global temperature limit, as global temperature is already 1.1° Celsius above pre-industrial level, and this determines local mean temperature. For instance, statistics show that Nigeria's mean temperature rose from about 26.98° Celsius three decades ago to approximately 27.27

and 27.45° Celsius in the last two decades, respectively (The World Bank n.d.). This signifies that much still has to be done to avoid dangerous and irreversible consequences of climate change pushing about 132 million of the world's population into poverty (IPCC n.d.; The World Bank n.d.).

Over the years (2010–2020), the agricultural, industrial and services sectors have contributed about 22 percent, 25 percent and 53 percent to gross national product in Nigeria and employed 35, 12, and 53 percent of the labour force, respectively (The World Bank n.d.). The relationship between climate change and these sectors is well documented, with the argument that climate change impacts negatively on the sectors (Tanure et al. 2020; Foye 2018; Foye and Benjamin 2021; Graff Zivin, Hsiang, and Neidell 2018). This suggests that the consequences of climate change could result in a very devastating decline in income and saving which are consequent to the movement of macro prices (see Bofinger and Ries 2017) and the welfare of every population. Unfortunately, the climate change mitigation policies (National environmental policy, National drought and desertification policy, National forest policy, National erosion and flood control policy) designed to curb climate change (most importantly the reduction of fossil fuel consumption) have substantial economic impacts on income, consumption and saving, as these sectors are mostly reliant on fossil fuels for existence in Nigeria (Foye and Benjamin 2021). In précis, the impact of climate change on macro prices is worrisome in Nigeria, given that Nigeria lacks the capacity to cope with the consequences of climate change because of its reliance on the environment for livelihoods, high rate of poverty incidence, poor energy and road infrastructures, accelerated degradation of resources, conflicts, weak governance and, lately, high insecurity for lives and properties. For instance, this is manifested in the current escalation in prices; particularly, food prices have tripled over the past decade in Nigeria, as the consumer price index which was 110.84 in 2011 became 324.99 in 2020. In the same vein, the exchange rate of naira to American dollar has more than doubled over the same period from N153.86 to N358.81 per dollar, and this has had a tremendous effect on the interest rate which increased from 6.25 percent in 2010, to 12 percent in 2011 and was 13.5 percent in 2020 after hovering between 12–14 percent in 2012–2018 (CBN 2020). The implications of rising macro prices are of great concern. An increase in food prices alone could move millions of Nigerians into poverty characterised by uncertainty, welfare, and investment losses, through lower real wages, higher input prices, and reduced international competitiveness. On the other hand, an exchange rate hike weakens foreign earnings which reduces availability of funds to priority sectors, thereby reducing economic activities, employment, per capita income and, again, the welfare of the citizens. In the same manner, a higher interest rate means lower investment and economic activities, an increase in unemployment and a reduction in income and welfare of the population (Adedeji and Foye 2019). Therefore, reversing this status quo is non-negotiable for Nigeria.

Furthermore, the importance of dealing with these different macro prices in a study cannot be overemphasised, as they are interrelated. Studies have shown that trying to mitigate the consequences of climate change on food-price hikes by employing inflation targeting measures (through interest rates), reduces investment and income. On the other hand, increasing money supply and exchange rate equally increases food prices which reduces real income, saving and investment (Monfared and Akın 2017). In fact, for a country like Nigeria, the exchange rate could be volatile and harmful, given the flexible exchange rate regime (Barguellil, Ben-Salha, and Zmami 2018) which engenders volatility effortlessly. Hence, analysing these macro prices together in a study could be a panacea to solving the consequences of climate change on macro prices in Nigeria, as the prices are highly interdependent. In synopsis, changes in food prices influence interest rate, and interest rate impacts exchange rate negatively. So, also, do exchange rate and interest rate influence food prices (see Arshad and Ali 2016; Adedeji and Foye 2019; Bofinger and Ries 2017) and climate change studies have avowed that international trade and tourism, among others, are drivers of exchange rate instability (Lee et al. 2021; Mckibbin et al. 2017; Tol 2006). Hence, it is imperative to propose relevant and adequate policy initiatives and solutions for this topical issue in Nigeria, in order to position the economy among the emergent world.

Against this backdrop, this study seeks to determine the extent to which climate change affects macro prices in Nigeria by employing a nonlinear autoregressive distributed lag (NARDL) method of econometric analysis using 1960–2019 data. This is because most macro relationships are innately nonlinear (Cosmas, Chitedze, and Mourad 2019; Nisbet, Miner, and Yale 2018) and need to be analysed thus. Moreover, the results of a nonlinear model are not only parsimonious and reliable but also very interpretable, providing a better fit with unbiased estimators and smaller residual errors (Bates and Watts 2007; Nisbet, Miner, and Yale 2018; Foye 2020). In addition, the NARDL allows asymmetry, switching from short run to long run and vice versa. Specifically, this study contributes to knowledge by analysing the extent to which climate change affects macro prices and also by determining the individual and the relative effects of climate change on macro prices in a nonlinear analysis and in the same study argues for adequate policy initiatives in a vulnerable economy like Nigeria.

The second section of this paper reviews past literature on climate change and macro prices while the third section unveils the research method. The fourth section shows the results and discussion of findings and the last section contains the recommendations and concluding remarks.

Review of Literature

THEORETICAL REVIEW

While other theories associate changes in price level with production, Milton Friedman relates this to monetary factors. The monetarists avow that changes in demand for and supply of money are closely linked to changes in general price level, food prices inclusive. This simply means the supply of money engenders an increase in food prices. The monetarists consider the monetary policy as a better equilibrating tool for any economy than the fiscal policy. On the other hand, the Keynesian school associates changes in price level with aggregate demand components, such as consumption which is a function of income, *ceteris paribus;* investment, a function of interest rate, and saving from income; as well as government spending and international trade. And over time economists have found that many other factors determine change in prices. For instance, foreign exchange, the saving-investment gap, the effects of agricultural output and its value chain, research and development, governance, and the institutional framework, among others, equally determine prices in general (Okoye et al. 2019; Inim, Samuel, and Prince 2020).

In the same vein, the classical theory uses the forces of demand for investment and supply of savings to determine interest rate while the balance of payments (BOP) theory of exchange rate maintains that the rate at which the currency of one country exchanges for another is determined by autonomous domestic price level and money supply. This means that the demand for foreign exchange is provoked by the demand for foreign goods and services, probably as a result of internal inflation. The theory of interest rate started with Fisher in 1930. This states that interest rate is a 'deviation from the price of the present money in terms of future money due to expected inflation'. This is commonly represented as $i = r + \pi$ (where i is the interest rate, r is the ex-ante real interest rate and π is the expected rate of change in the price level), which is a result of the efficiency of labour and capital as well as time preference of investors in an economy. Further, Fankhauser, Smith, and Tol (1999) and Foye (2014; 2018) have unveiled the relationship between climate change and macroeconomic activities both theoretically and empirically.

EMPIRICAL REVIEW

It is a consensus that macro prices are influenced by climate change (Food and Agriculture Organisation of the United Nations 2019a; Galindo, Reyes, and Alatorre 2015; Iheoma 2014; Mckibbin et al. 2017; Ogbuabor et al. 2020; Bhalia 2021). Thus, there are innumerable studies on the impact of climate change on food prices which is a core portion of the consumer price index and one of the determinants of increase in the general price level, and all of these studies are in agreement that climate change impacts negatively on food prices, given that most regions rely on the environment for food. However, African and Asian countries seem to be more affected because they are most vulnerable to climate change. The implication of this is clear for these countries, as they might be induced to rely more on food imports (see Mckibbin et al. 2017; Igbokwe-Ibeto 2019; Shuaibu 2020 among others). However, Food and Agriculture Organisation of the United Nations (2019b) submitted that this impact could be low in open economies. Specifically, studies by Bandara and Cai (2014), Bradbear and Friel (2013), Hendrix and Haggard (2015), and Stevanović et al. (2016) employed a partial equilibrium approach using a global dynamic computable general equilibrium model, conceptual development, panel ordinary least squares regression, a global partial equilibrium agro-economic model (The Model of Agricultural Production and its Impact on the Environment, or MAGPIE model) and descriptive statistics, respectively, and found that climate change escalates food prices; hence, inflation. However, studies by Kreidenweis et al. (2016) and Stevanović et al. (2016) elucidated that an increase in food prices is not only a result of the direct impact of climate change on agriculture but also that the cost of adapting and mitigating the effects of climate change is germane in the movement of food prices. To this effect, this study seeks to establish the extent of this food price increase in the presence of other macro prices.

On the relationship between climate change and exchange rate, Feyen

TABLE 1 Summary of Empirical Review

(1)	(2)	(3)	(4)	(5)
Climate change and food Prices	Bandara and Cai (2014)	South Asia (Bangladesh, India, Nepal, Pakistan and Sri Lanka)	Partial equilibrium approach using global dynamic computable general equilibrium model	South Asia is one of the most vulnerable regions where climate-induced changes exert a significant negative impact on food prices.
	Howard and Sterner (2014)	USA	Modified Dynamic Integrated Climate-Economy (DICE) model, an integrative assessment model	Accounting for relative prices of agricultural and non-market goods increases the damage estimates of climate change (social cost of carbon) from $38 to about $52, showing that the cost of climate change is greater than reported.
	Hendrix and Haggard (2015)	Developing Countries: 49 countries in Africa and Asia (1961–2010)	Panel ordinary least squares regression	Climate change would induce the reliance of many developing countries on food imports, which would result in food price increase and volatility.
	Raleigh, Choi, and Kniveton (2015)	113 African markets (Jan 1997 to April 2010)	Simultaneous equation models	Climate change increases shortages in food production, thereby increasing food prices and these results in conflicts which lead again to further food price hikes.
	Food and Agriculture Organisation of the United Nations (2016)	Global	Descriptive Statistics	Climate change engenders food price increases and volatility, thereby reducing purchasing power and thus restricting access to food. This in turn affects the lives and livelihoods of poor net food buyers.

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et al. (2020) employed data spanning from 2005–2017 for panel data analysis of the global economy and found that most countries are vulnerable to climate change and macro-financial risks. Particularly for MENA countries, climate change could reduce foreign exchange earnings as they face the transition and macro-financial vulnerability risks. However, Batten, Sowerbutts, and Tanaka (2020) unveiled in their studies the inter-

TABLE 1 *Continued from the previous page*

(1)	(2)	(3)	(4)	(5)
	Kreidenweis et al. (2016)	Global	Global partial equilibrium model (MAGPIE model)	Mitigating climate change through afforestation would engender a more than fourfold increase in food prices by 2100, as afforestation competes for available arable land for food crops cultivation.
	Stevanović et al. (2016)	Global	Global partial equilibrium agro-economic model (MAGPIE model)	Climate incentive-based mitigation policies reduce the availability of land, which in turn increases production costs and food prices. The preference-based mitigation reduces land scarcity, inhibits emissions leakage, and focuses on the most productive locations, which invariably lowers food prices.
	Mckibbin et al. (2017)	Global	Reviews/ descriptive statistics	Increase in food prices could result in inflation; the response of a central bank determines what happens to the exchange rate. In inflation targeting, the interest rate is raised which slows down the economy more, causing the exchange rate to appreciate, making imports cheaper and exports more expensive. An income targeting initiative is more attractive, as it does not create public expectations of higher future inflation.
	Aye and Haruna (2018)	Nigeria (1995–2009)	Descriptive statistics and three-stage least square regression method	Climate change especially affects the price of maize negatively in Benue state in Nigeria.
	Igbokwe-Ibeto (2019)	Nigeria	Descriptive statistics	Climate change causes hikes in food prices. Worse cases of food crisis are imminent in Nigeria.

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dependence of macro prices, using descriptive statistics and conceptual development for the United States of America (USA) in 2006–2019. Their result revealed that climate change affects food and energy prices, engendering inflation which makes a country less competitive, suggesting

TABLE 1 *Continued from the previous page*

(1)	(2)	(3)	(4)	(5)
	Food and Agriculture Organisation of the United Nations (2019b)	Global	Descriptive statistics	Climate change causes food insecurity, hikes in food prices and general price levels. However, the effects could be low in open economies.
	Shuaibu (2020)	Nigeria	Nonlinear ARDL	Climate change affects food production and food prices. The result concludes that asymmetries exist in the long run only.
Climate change and exchange rate	Tol (2006)	16 major regions of the world (1950 to 2200)	Integrated Assessment Model Version 2.7 of the Climate Framework for Uncertainty, Negotiation, and Distribution (FUND)	The impact of climate change is determined by the type of foreign exchange employed in analysis. It is projected that developing countries would grow more slowly when a purchasing power exchange rate is employed than with a market exchange rate. The study argues that the market exchange rate is more appropriate for international trade, and the real exchange rate for international welfare comparisons.
	Economic Commission for Latin America and the Caribbean (2011)	Montserrat (2008–2050)	Descriptive statistics/ a general structural time series model	Montserrat is dependent on tourism which earns more than five times the value of its merchandise exports; and being affected by the consequences of climate change means a decline in foreign exchange earnings which is consequent to the Island's exchange rate.
	Feyen et al. (2020)	Global 1981–2017 and1995–2017 for descriptive statistics; 2005–2017 for panel analysis	Descriptive statistics/ panel data analysis	Countries are vulnerable to climate change, even macro-financial risks. Climate change could reduce foreign exchange earnings in MENA countries, as they face the transition and macro-financial vulnerability risks.

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a decline in foreign exchange in the long run. Accordingly, attendant climate change and carbon emissions policies affect the monetary policy objectives of the USA. Lee et al. (2021) extended the frontiers of knowl-

TABLE 1 *Continued from the previous page*

(1)	(2)	(3)	(4)	(5)
	Batten, Sowerbutts, and Tanaka (2020)	United States of America (2006–2019)	Descriptive statistics and conceptual development	Climate change and carbon emissions policies affect monetary policy objectives. Climate change affects food and energy prices, engendering inflation which makes a country less competitive. This suggests a decline in foreign exchange in the long run.
	Lee et al. (2021)	76 countries (1970–2017)	Stochastic discount factor approach/ Impulse response from single-equation method	38% of the selected countries which are poorer, less reliant on agriculture, and engage in international trade have their exchange rates appreciate in real terms against the US dollar, especially for landlocked countries, while the real exchange rate depreciates in 17% of the selected countries which are warmer, wealthier, more reliant on agriculture and tourism, and are less open.
	Bhalia (2021)	Kenya	Descriptive Statistics	Climate change ravages tea production which is a major source of foreign exchange for Kenya. This means the likelihood of the domestic exchange rate's depreciation against the dollar is strong.

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edge by carrying out a study on 76 countries consisting of countries that are open to external trade and those that are less open, in the presence of both local and global climate change shocks. They discovered that real exchange rate responds to both global and country-specific temperature shocks. However, only the responses to global shocks systematically show country characteristics, as 38% of the selected countries which are poorer, less reliant on agriculture, and engage in international trade have their exchange rates appreciate in real terms against the US dollar, particularly for landlocked countries. On the other hand, the real exchange rate depreciates in 17% of the selected countries which are warmer, wealthier, more reliant on agriculture and tourism, and are less open to international trade. This suggests that countries that are warmer and most reliant on agriculture suffer the negative consequences of climate change more.

For the final strand in this study, Mckibbin et al. (2017), in their study of climate change and monetary policy, revealed that the effect of climate

TABLE 1 *Continued from the previous page*

(1)	(2)	(3)	(4)	(5)
Climate change and interest rate	Tumwine et al. (2018)	Uganda (24 banks; 2008–2016)	Net interest margin model/panel random-effects regression method	Liquidity, equity capital, market power, and reserve requirement have a positive and significant effect on interest rate while operational efficiency, lending out ratio, concentration, public sector borrowing, and private sector credit harm the interest rate. Climate change is not included in this analysis.
	Bylund and Jonsson (2020)	General	Descriptive statistics	Climate change weakens growth, increases uncertainty, and elevates the risk of disasters which could engender a low long-run real interest rate. The too-low long-run interest rate might make it difficult for apex banks to achieve price stability.
	Bauer and Rudebusch (2021)	General	Descriptive statistics	The study shows that the fundamental anchor for the market-based social discount rate is the equilibrium real interest rate. Empirical interest rate models have declined significantly since the 1990s and this has made the entire term structure of social discount rates to decline as well. This new normal of persistently lower interest rates boosts the social cost of carbon and supports a climate policy with stronger carbon mitigation strategies.
	Rudebusch (2021)	General	Letters	Climate change is a strong source of financial risk for households and businesses. Although there is a great deal of uncertainties, still, central banks have made progress on a path to identify, assess, and manage climate-related financial risks.

NOTES Column headings are as follows: (1) titles, (2) authors, (3) country, (4) theoretical framework/methodology, findings.

change on interest rate is mostly the upshot of the carbon emissions policies employed to mitigate the consequences of climate change. For instance, policy initiatives to stabilise a climate-induced price increase may be targeted at the interest rate; hence, the link between climate change and interest rate might be essentially indirect. However, the implication of raising the interest rate by central banks is further slowdown in economic activities, making imports cheaper and exports more expensive. This suggests that an income-targeting initiative is more attractive and should be a better way of targeting inflation, given that it does not create public expectations of higher future inflation. Further, Bylund and Jonsson (2020) employed descriptive analysis and found that climate change weakens economic growth, increases uncertainty, and elevates the risk of disasters which could engender a low long-run real interest rate. This low long-run interest rate might make it difficult for apex banks to achieve price stability. Just like Bylund and Jonsson (2020), Bauer and Rudebusch (2021) showed that long-run equilibrium real interest rate has declined since the 1990s, causing the entire term structure of social discount rates to decline and confirming the importance of the real interest rate in the present discounted future costs of climate change. This confirms that there is a link between the discount rates, the long-run equilibrium real interest rate and climate policies generally. The lower interest rates boost the social cost of carbon and support a climate policy with stronger carbon mitigation strategies.

Specifically, three strands of the literature are considered in this review. First are studies on the link between climate change and food prices, second are those on foreign exchange, and lastly, those on the relationship between climate change and interest rate. Finally, most studies on climate change and macro prices are cross-country analyses (see Bauer and Rudebusch 2021; Lee et al. 2021; Food and Agriculture Organisation of the United Nations 2019b; Hendrix and Haggard 2015; Raleigh, Choi, and Kniveton 2015; Stevanović et al. 2016) which do not control for the country-specific peculiarity of Nigeria, one of the most vulnerable populations and a very fragile economy. Furthermore, most of the studies are anecdotal, as they only utilised descriptive statistics which lack rigorous methodological control. Others employed integrated assessment models (IAMS) which exaggerate climate values and suffer from technical deficiencies, as it is difficult to specify optimal paths through IAMS (Ackerman et al. 2009).

See Table 1 (pp. 173–177) for the summary of the empirical literature review.

Materials and Methods

There are three theoretical frameworks in this study. For food prices, I follow Huh and Park (2013) on the factors that influence inflation, while for the exchange rate and interest rate I follow Frankel (2007) and Feldstein and Eckstein (1970), respectively. Following Fankhauser and Tol

(2005), I employ climate change as one of the core explanatory variables in this study. Also, trade openness is included because Nigeria is an open economy, and Lee et al. (2021) have equally submitted after studying 76 economies that 38% of the economies who maintained open economy policies experienced currency appreciation.

THEORETICAL FRAMEWORK

The description and measurement of the variables employed in this study are important and therefore stated thus: food prices (FP) and exchange rate (EXR) are measured by consumer price index and Nigeria's naira relative to the United States' dollar, respectively. While money supply (MS) is measured by broad money, interest rate (IR) is measured by the Central Bank of Nigeria's nominal interest rate. Finally, trade openness is measured by percentage of trade to gross domestic product, and climate change (CC) by atmospheric mean temperature.

Model 1 (Food Prices as Dependent Variable)

Following Huh and Park (2013) on the relevant regressors for Food Prices (FP) in this study, I specify $\text{FP} = f(\text{EXR}, \text{MS}, \text{IR}, \text{TO}, \text{CC})$ where (i) the Exchange Rate (EXR) against the dollar can affect local food prices by altering import prices, (ii) Money Supply (MS) is included to reflect inflationary pressures on the general price level, (iii) Interest Rate (IR) is incorporated because a change in interest rate changes demand for money and hence food prices (high interest rates reduce firms' desire to carry inventory (Frankel 2014), and (iv) International trade (TO) is included, first because Nigeria is an open economy and second, because high food prices could engender increased import and vice versa (Lee et al. 2021). Finally, (v) Climate Change (CC) variable (average temperature) is included because climate change affects food production and food prices (Shuaibu 2020).

Model 2 (Foreign Exchange as Dependent Variable)

Following Frankel (2007) on the relevant regressors for Exchange Rate (EXR), I specify Model 2 as $\text{EXR} = f(\text{FP}, \text{MS}, \text{IR}, \text{TO}, \text{CC})$. This simply reveils that: (i) Changes in price level, in this case food prices, would cause changes in dollar exchange rate: a country with lower commodity prices would experience appreciation in foreign currency, as lower prices encourage exports; hence, foreign exchange. (ii) On the other hand, changes in interest rate affect exchange rate; this is because increases in interest rate provide higher rates to lenders and this attracts foreign capital, hence increase in money supply. (iii) Furthermore, engagement in trade increases net export, therefore trade openness is included in this model. (iv) Average temperature is equally included in the exchange rate model to capture climate change, given the fact that climate change policies affect monetary policy objectives and inflation which makes an economy less competitive in trade when compared to other economies (Batten, Sowerbutts, and Tanaka 2020).

Model 3 (Interest Rate as Dependent Variable)

Following Feldstein and Eckstein (1970) on the relevant fundamental determinants of interest rate (IR) for this study, I specify IR $= f($MS, FP, EXR, TO, CC$)$ where the basic Keynesian liquidity preference theory advances that there is a relationship between the quantity of money, the level of income and the rate of interest which is empirically expressed in a money demand function.

However, a more appropriate relationship is that of interest rate and money supply which equally determines the changes in price level but not a continuous rise in price level (in this model food prices (FP) is therefore employed). Likewise, a higher interest rate attracts trade and increases foreign exchange. Very recently, the uncertainties and risk associated with climate change have made it a topical issue in macro-financial models; hence we also include climate change in the interest rate model (Bylund and Jonsson 2020).

SPECIFICATION OF MODELS

Given that macroeconomic variables are essentially nonlinear and their processes are well recognised and established in literature (Cosmas, Chitedze, and Mourad 2019; Nisbet, Miner, and Yale 2018; Shin, Yu, and Greenwood-Nimmo 2014), the explanatory variables of the three models in this study are, therefore, specified following Shin, Yu, and Greenwood-Nimmo (2014) and Foye, Adedeji, and Babatunde (2020). First, I specify generic partial sums x_t^+ and x_t^- around zero with the view to distinguishing between positive and negative changes in the rate of growth of x_t. This is because the imposition of long-run symmetry where the relationship is actually nonlinear will inhibit efforts to test for the presence of a stable long-run relationship and this can result in spurious dynamic responses. In the same vein, it is important to capture asymmetries correctly. This will help to unveil probable differences in the responses of economic agents to positive and negative shocks.

$$x_t^+ = \sum_{j=1}^{t} \Delta x_j^+ = \sum_{j=1}^{t} \max(\Delta x_j, 0)$$
$$x_t^- = \sum_{j=1}^{t} \Delta x_j^- = \sum_{j=1}^{t} \min(\Delta x_j, 0) \qquad (1)$$

Furthermore, I develop a parametric dynamic model for combined long-run and short-run asymmetries by extending the ARDL method of Pesaran and Shin (1999) and Pesaran, Shin, and Smith (2001); therefore, the nonlinear ARDL model is specified thus:

$$y_t = \sum_{i=1}^{p} \gamma_i y_{t-i} + \varepsilon_t \sum_{j=0}^{m} (\varphi_j^+ \Delta x_{t-j}^+ + \varphi_j^- \Delta x_{t-j}^-) + \varepsilon_t, \qquad (2)$$

where x_t is the $k \times 1$ vector of multiple regressors, φ_j^+ and φ_j^- are the asymmetric distributed-lag parameters, and ε_t is white noise. I rewrite Equation (2) in an error correction format as

$$\Delta y_t = \alpha_0 + \theta_{yy} y_{t-1} + \theta_{yx}^+ x_{t-1}^+ + \theta_{yx}^- x_{t-1}^-$$
$$+ \sum_{i=1}^{p} \gamma_i \Delta y_{t-i} + \sum_{j=0}^{m-1} (\varphi_j^+ \Delta x_{t-j}^+ + \varphi_j^- \Delta x_{t-j}^-) + \varepsilon_t, \qquad (3)$$

where x_t^+ and x_t^- are the positive and negative movements of variables in x_t in the long run, θ_{yx}^+ is the long-run cointegrating relationship between y_t and x_t^+, and θ_{yx}^- is the long-run cointegrating relationship between y_t and x_t^-.

y_t, x_t^+, and x_t^- form the nonlinear long-run equilibrium while the last summation term is the asymmetric error correction process of the nonlinear model. $\theta_{yx}^+ = \theta_{yx}^-$ represents the long-run symmetry and $\sum_{j=0}^{m-1} \varphi^+ = \sum_{j=0}^{m-1} \varphi^-$ the short-run symmetry; and can be tested using the standard Wald tests. Following Shin, Yu, and Greenwood-Nimmo (2014), the bounds test of ARDL is applied to nonlinear ARDL, and also the Pesaran critical values are equally appropriate and employed in determining cointegration. The critical values are selected based on the number of variables before decomposition into partial sums.

Therefore, I rearrange and respecify the basic three models implicitly:

$$\text{FP} = f(\text{CC}, \text{MS}, \text{IR}, \text{EXR}, \text{TO}, \mathcal{U}) \quad (4)$$

$$\text{EXR} = f(\text{CC}, \text{MS}, \text{IR}, \text{FP}, \text{TO}, \mathcal{U}) \quad (5)$$

$$\text{IR} = f(\text{CC}, \text{MS}, \text{FP}, \text{EXR}, \text{TO}, \mathcal{U}) \quad (6)$$

Equations (7), (8), and (9) are the econometric representation of Equations (4), (5), and (6):

$$\text{FP} = \phi_0 + \phi_1\text{CC}_t + \phi_2\text{MS}_t + \phi_3\text{IR}_t + \phi_4\text{EXR} + \phi_5\text{TO}_t + \varepsilon_t \quad (7)$$

$$\text{EXR} = \phi_0 + \phi_1\text{CC}_t + \phi_2\text{MS}_t + \phi_3\text{IR}_t + \phi_4\text{FP} + \phi_5\text{TO}_t + \varepsilon_t \quad (8)$$

$$\text{IR} = \phi_0 + \phi_1\text{CC}\phi_t + \phi_2\text{MS}_t + \phi_3\text{FP}_t + \phi_4\text{EXR} + \phi_5\text{TO}_t + \varepsilon_t \quad (9)$$

The general form of the asymmetric ARDL model is then represented thus:

$$\begin{aligned}\text{FP} = {} & \phi_0 + \phi_1\text{CC}\phi_t^+ + \phi_2\text{CC}_t^- + \phi_3\text{MS}\phi_t^+ + \phi_4\text{MS}_t^- + \phi_5\text{IR}_t^+ \\ & + \phi_6\text{IR}_t^- + \phi_7\text{EXR}_t^+ + \phi_8\text{EXR}_t^- + \phi_9\text{TO}_t + \varepsilon_t \quad (10)\\ \text{EXR} = {} & \phi_0 + \phi_1\text{CC}_t^+ + \phi_2\text{CC}_t^- + \phi_3\text{MS}_t^+ + \phi_4\text{MS}_t^- + \phi_5\text{IR}_t^+ + \\ & + \phi_6\text{IR}_t^- + \phi_7\text{FP}_t^+ + \phi_8\text{FP}_t^- + \phi_9\text{TO}_t + \varepsilon_t \quad (11)\\ \text{IR} = {} & \phi_0 + \phi_1\text{CC}_t^+ + \phi_2\text{CC}_t^- + \phi_3\text{MS}_t^+ + \phi_4\text{MS}_t^- + \phi_5\text{FP}_t^+ + \\ & + \phi_6\text{FP\_}t^- + \phi_7\text{EXR}_t^+ + \phi_8\text{EXR}_t^- + \phi_9\text{TO}_t + \varepsilon_t, \quad (12)\end{aligned}$$

where FP is Food Prices (measured by consumer price index), CC is Climate change (measured with atmospheric mean temperature), MS is Money Supply (measured by broad money), IR is Interest Rate (measured by the Central Bank of Nigeria's nominal interest rate), EXR is Exchange rate (measured by Nigeria's naira relative to the United States' dollar), TO is Trade openness (measured by percentage of trade to gross domestic product), $\phi_1 - \phi_9$ is Vector of long-term parameters, and ε_t is Error term.

Climate change (global warming) is measured in the same context for every country using mean atmospheric temperature because climate change is a global phenomenon (Abidoye and Odusola 2015; Foye 2018; Foye and Benjamin 2021; Kiley 2021). Climate change in this sense is different from short-term weather patterns which are important for studies on agricultural productivity. Also, it is worthy of note to emphasise that rainfall patterns are driven by the earth's temperature (see Foye 2014; United States Environmental Protection Agency n.d.b). Hence, the key focus and measure of climate change in this study is the mean atmospheric temperature which has low frequency, and the macro prices are dependent on it in these models; therefore, the employment of annual data is appropriate for this study (Cheung et al. 2017; Yeo and Kim 2014).

Integrating Equation 1 into the NARDL model for the three models, I have:

$$\begin{aligned}
\text{FP} = {} & \gamma + \eta_0\text{FP}_{t-1} + \eta_1\text{CC}^+_{t-1} + \eta_2\text{CC}^-_{t-1} + \eta_3\text{MS}^+_{t-1} + \eta_4\text{MS}^-_{t-1} \\
& + \eta_5\text{IR}^+_{t-1} + \eta_6\text{IR}^-_{t-1} + \eta_7\text{EXR}^+_{t-1} + \eta_8\text{EXR}^-_{t-1} + \eta_9\text{TO}_{t-1} \\
& + \sum_{i=1}^{p}\theta_i\Delta\text{FP}_{t-i} + \sum_{i=0}^{q}(\vartheta_i^+\Delta\text{CC}^+_{t-i} + \vartheta_i^-\Delta\text{CC}^-_{t-i}) \\
& + \sum_{i=0}^{r}(\lambda_i^+\Delta\text{MS}^+_{t-1} + \lambda_i^-\Delta\text{MS}^-_{t-1}) + \sum_{i=0}^{s}(\varphi_i^+\Delta\text{IR}^+_{t-i} + \varphi_i^-\Delta\text{IR}^-_{t-i}) \\
& + \sum_{i=0}^{t}(\psi_i^+\Delta\text{EXR}^+_{t-i} + \psi_i^-\Delta\text{EXR}^-_{t-i}) + \sum_{i=1}^{u}\Omega_i\Delta\text{TO}_{t-i} + \mu_t, \qquad (13)
\end{aligned}$$

$$\begin{aligned}
\text{EXR} = {} & \gamma + \eta_0\text{EXR}_{t-1} + \eta_1\text{CC}^+_{t-1} + \eta_2\text{CC}^-_{t-1} + \eta_3\text{MS}^+_{t-1} + \eta_4\text{MS}^-_{t-1} \\
& + \eta_5\text{IR}^+_{t-1} + \eta_6\text{IR}^-_{t-1} + \eta_7\text{FP}^+_{t-1} + \eta_8\text{FP} + \eta_9\text{TO}_{t-1} \\
& + \sum_{i=1}^{p}\theta_i\Delta\ln\text{EXR}_{t-i} + \sum_{i=0}^{q}(\vartheta_i^+\Delta\text{CC}^+_{t-i} + \vartheta_i^-\Delta\text{CC}^-_{t-i}) \\
& + \sum_{i=0}^{r}(\lambda_i^+\Delta\text{MS}^+_{{}_{t-1}} + \lambda_i^-\Delta\text{MS}^-_{t-1}) + \sum_{i=0}^{s}(\varphi_i^+\Delta\text{IRT-I}^+ + \varphi_i^-\Delta\text{IR}^-_{t-i}) \\
& + \sum_{i=0}^{t}(\psi_i^+\Delta\text{FP}^+_{t-i} + \psi_i^-\Delta\text{FP}^-_{t-i}) + \sum_{i=1}^{u}\Omega_i\Delta\text{TO}_{t-i} + \mu_t, \qquad (14)
\end{aligned}$$

$$\begin{aligned}
\text{IR} = {} & \gamma + \eta_0\text{IR}_{t-1} + \eta_1\text{CC}^+_{t-1} + \eta_2\text{CC}^-_{t-1} + \eta_3\text{MS}^+_{t-1} + \eta_4\text{MS}^-_{t-1} \\
& + \eta_5\text{IR}^+_{t-1} + \eta_6\text{IR}^-_{t-1} + \eta_7\text{FP}^+_{t-1} + \eta_8\text{FP} + \eta_9\text{TO}_{t-1} \\
& + \sum_{i=1}^{p}\theta_i\Delta\text{IR}_{t-i} + \sum_{i=0}^{q}(\vartheta_i^+\Delta\text{CC}^+_{t-i} + \vartheta_i^-\Delta\text{CC}^-_{t-i}) \\
& + \sum_{i=1}^{r}(\lambda_i^+\Delta\text{MS}^+_{t-1} + \lambda_i^-\Delta\text{MS}^-_{t-1}) + \sum_{i=0}^{s}(\varphi_i^+\Delta\text{FP}^+_{t-i} + \varphi_i^-\Delta\text{FP}^-_{t-i}) \\
& + \sum_{i=0}^{t}(\psi_i^+\Delta\text{EXR}^+_{t-i} + \psi_i^-\Delta\text{EXR}^-_{t-i}) + \sum_{i=1}^{u}\Omega_i\Delta\text{TO}_{t-i} + \mu_t, \qquad (15)
\end{aligned}$$

where p, q, r, s, t, and u are the lag orders; $\phi_i = \eta_i^+$ and η_i^- are the long-run impacts of the increases and decreases of the first four pairs of long-term regressors on FP, EXR and IR respectively. Also, each pair of $\sum_{i=0}^{q} \theta_i^+$ and $\sum_{i=0}^{q} \theta_i^-$, $\sum_{i=0}^{r} \lambda_i^+$ and $\sum_{i=0}^{r} \lambda_i^-$, $\sum_{i=0}^{s} \lambda_i^+$ and $\sum_{i=0}^{s} \varphi_i^-$, $\sum_{i=0}^{t} \psi_i^+$ and $\sum_{i=0}^{t} \psi_i^-$ capture the short-run impacts of the increases and decreases of the short-term regressors on FP, EXR, and IR, respectively. Furthermore, I extend Equations (13)–(15) by including an endogenous structural breaks dummy variable ($\sum_{r=1}^{v} \delta D_{rt}$) to capture significant events that could induce structural change in the variables employed in this study given that the observational period of the data covers decades which hold structural events such as Nigeria's structural adjustment programme of 1986, the political instability of 1993–1994, the bank recapitalisation of 1991 and 1994, the global melt down of 2008, the collapse of oil prices and output of 2014, among others. Therefore the $D_{rt} = 1$ for $t > T_D$, and $D_{rt} = 0$, where the time period is t and T_D are the structural break dates when $r = 1, 2, 3, \ldots, k$ and δ_r is the coefficient of the structural break dummy. The Bai-Perron test (Bai and Perron 2003) which determines multiple breaks endogenously is employed in this study to overcome bias associated with regression results in the presence of structural breaks.

DATA AND TECHNIQUES OF ANALYSIS

This study employs the NARDL bounds testing technique in the analysis of three macro-price models in Nigeria from 1960 to 2019. This observational period is large enough to make room for the required degrees of freedom. Annual time-series data on food prices (measured by consumer price index), exchange rate, and interest rate (measured by the Central Bank of Nigeria's monetary policy rate) are sourced from Central Bank of Nigeria (CBN 2020) while data for broad money supply, trade openness, and climate change are obtained from the World Development Indicators (The World Bank n.d.) and climate knowledge portal of 2020. The EViews 10 statistical package is used in the analysis of the data. I ascertain that variables with the second order of integration [I(2)] are not included in the models to avoid their crashing which could result in invalid estimated bounds F-statistics (Pesaran 1997; Haug and Ucal 2019; Allen and McAleer 2021). Therefore, I employ Kapetanios, Shin, and Snell (2003), and Kruse (2011) tests to ensure there is no I(2) series in the models. This is done after observing the summary statistics which show the distribution of the data being employed. The nonlinear ARDL performs better in determining cointegration in small samples (Iyke and Ho 2017)

TABLE 2 Summary Statistics with Raw Data

Item	FP	EXR	IR	CC	MS	TO
Mean	39.99	61.43	10.14	26.98	4580.00	31.96
Median	2.33	7.70	10.00	26.99	50.50	32.45
Maximum	267.51	306.92	26.00	27.83	34800.00	53.28
Minimum	0.07	0.55	3.50	26.21	0.28	9.14
Std. Dev.	65.58	87.01	5.19	0.39	9090.00	11.39
Skewness	1.88	1.38	0.57	−0.09	2.04	−0.15
Kurtosis	5.80	4.05	2.79	2.35	5.98	2.25
Jarque-Bera	55.00	21.73	3.33	1.12	63.79	1.65
(Prob.)	(0.00)	(0.00)	(0.19)	(0.57)	(0.00)	(0.44)

NOTES The first five cells under MS in the raw results are in trillion naira.

and its framework can test for symmetry in the short run and long run. It is noteworthy to highlight that the presence of symmetry reduces the NARDL equation to an ARDL equation. The NARDL model is parsimoniously specified to maintain adequate degrees of freedom. This study employs automatic lag length selection based on the Akaike Information Criterion. The data obtained for Models 1–3 cover the periods of 1960–2019.

Results and Discussion

DESCRIPTIVE STATISTICS

Data observation is very important in economic modelling. It helps to overcome the challenge of spurious regression caused by outliers and the abnormal distribution of data. Table 2 shows the summary statistics of the raw data for Models 1–3. IR, CC, and TO are normally distributed with Jarque-Bera probability values that are greater than a 0.05 level of significance while FP, EXR, and MS are not normally distributed. This observation can also be seen in the kurtosis and skewness of the variables. The kurtosis of almost 3 suggests that the series is in the range of normalcy (not peaked and not flat). Also, a non-zero value of skewness means variables are not normally distributed which is the case for the latter variables mentioned above.

Therefore, I take the natural log of the variables except those that are already in percentages (IR and TO) to achieve normal distribution of all the variables (Wooldridge 2018; see the results for the logged variable in table 3). The highest mean and median are 4580 and 50.5 trillion for MS re-

TABLE 3 Summary Statistics with Logged Data

Item	LNFP	LNEXR	IR	LNCC	LNMS	TO
Mean	1.14	2.12	10.14	3.30	25.19	31.96
Median	0.85	2.04	10.00	3.30	24.63	32.45
Maximum	5.59	5.73	26.00	3.33	31.18	53.28
Minimum	−2.72	−0.60	3.50	3.27	19.44	9.14
Std. Dev.	2.92	2.45	5.19	0.01	3.86	11.39
Skewness	0.07	0.16	0.57	−0.12	0.06	−0.15
Kurtosis	1.43	1.30	2.79	2.35	1.69	2.25
Jarque-Bera	6.19	7.53	3.33	1.18	4.36	1.65
(Prob.)	(0.05)	(0.02)	(0.19)	(0.55)	(0.11)	(0.44)

spectively while for IR they are the least at 10.14 and 10 in the same order. The first five cells under MS in the raw results are in trillion naira. The close values of the mean and median for the different variables are strong proofs that the data are normally distributed (see Holmes, Illowsky, and Dean 2017). The mean and the median values also authenticate that our population sample is large enough to reduce bias in the variance of our models. Finally, the maximum and the minimum values are not outliers, as they are still in close range with the observations of the respective variables.

Nevertheless, to have interpretable results and valid regression output, the data employed in this study are in natural logarithm except for IR and TO which are in rates (see Ogun 2021; Wooldridge 2018).

UNIT ROOT AND COINTEGRATION TESTS

Unit Root Tests

Although the regular linear unit root tests show that all variables are either stationary at level [I(1)] or first difference [I(1)] with no I(2) series, nevertheless the power of the test is too low to make a nonlinear stationarity conclusion (see Güriş 2017). Therefore, I employ Kapetanios, Shin, and Snell (2003), and Kruse (2011) to determine the nonlinear stationarity properties of the variables used in this study. The unit root test proposed by Kruse (2011) is an extension and better fit of Kapetanios, Shin, and Snell (2003). Specifically, Kapetanios, Shin, and Snell (2003) is a technique of testing for non-stationarity against a global alternative of a stationary nonlinear exponential smooth transition autoregressive (ESTAR) process. The Kruse nonlinear unit root test examines the ESTAR character-

TABLE 4 Nonlinear Unit Root Test Results

Variables	KSS	Kruse	Remarks	Variables	KSS	Kruse	Remarks
LNFP	−1.87	−1.73	Non stationary	LNCC	0.22	−3.42	Non stationary
LNEXR	−1.48	−2.66	Non stationary	LNMS	−1.99	−3.33	Non stationary
IR	−1.13	−5.49	Non stationary	TO	−2.94	−3.76	Non stationary

NOTES The 5 percent critical values for KSS and Kruse (2011). Tests are −2.88 and 9.57, respectively (see Hepsag 2017).

TABLE 5 Unit Root Test With Structural Breaks

Series	Vogesland test decision			Final decision
	Break year	I(0)	I(1)	
LNFP	1995	−2.78	−5.13*	I(1)
LNEXR	1999	4.46*	−8.31	I(0)
IR	1993	−4.06	12.52*	I(1)
LNCC	2000	−5.37*	11.99	I(0)
LNMS	2007	−1.82	−5.65*	I(1)
TO	1981	−3.53	−9.56*	I(1)
5% critical values		4.44	4.44	

istics against the null hypothesis of a unit root. The ESTAR and the Kruse equations used in determining the nonlinear stationarity properties of the variables in this study are $Y_t = \alpha Y_{t-1} + \beta Y_{t-1}[1 - \exp\{-\theta(Y_{t-1} - C)^2\}] + \varepsilon_t$ and $\Delta Y_t = \gamma_1 Y_{t-1}^3 + \gamma_2 Y_{t-1}^2 + \sum_{j=1}^{p} \delta_j \Delta Y_{t-j} + \varepsilon_t$, respectively. The Kruse equation extends the ESTAR's by using the Taylor approximation to test the null of unit root (see Foye 2020 and table 4).

In addition, the Vogesland unit root test which handles structural breaks is equally used to ensure there is no I(2) series in the models (see results in table 5).

Nonlinear ARDL Bounds Cointegration Tests

The nonlinear ARDL is employed when variables are I(0) or I(1) or a combination of both. The method equally corrects for endogeneity and serial correlation while allowing for possible asymmetry in the explanatory variables (see Foye, Adedeji, and Babatunde 2020; Pesaran and Shin 1999). This methodology of bounds test shows whether there is a long-run relationship among the variables of each model. The advantages of NARDL and the implications are well documented in Nusair (2016).

TABLE 6 Nonlinear ARDL Bounds Cointegration Test Results

Models: dep. variables	Est. F-statistic, NARDL	Decision
Model 1: LNFP	5.28***	Reject H0: Cointegration exists
Model 2: LNEXR	6.56***	Reject H0: Cointegration exists
Model 3: LNINT	7.07***	Reject H0: Cointegration exists

Model 1 has inflation as its dependent variable, Model 2 the exchange rate, and Model 3 employs interest rate as its dependent variable. Table 6 holds the bounds test results for the three models.

The F-statistics for all the models reveal that a long-run relationship exists among the variables, as their F-statistics of 5.28, 6.56, and 7.07 are greater than the Pesaran, Shin, and Smith (2001) critical values at a 95% confidence interval. This means there is evidence of cointegration in asymmetric modelling. This will allow dynamic analysis of climate change with the selected macro prices in Nigeria.

Table 7 shows the results of the nonlinear ARDL and the diagnostic tests for the three models. The selected models are ARDL(3, 0, 0, 3, 0, 2, 0, 3, 0, 2, 1), ARDL(2, 4, 3, 0, 4, 4, 4, 4, 3, 3) and ARDL(1, 0, 0, 0, 0, 2, 0, 2, 1, 0) for Models 1, 2, and 3, respectively. The lower right segment holds the results of the diagnostic tests. The serial correlation (Breusch-Godfrey) and stability (Cusum and Cusum of squares) tests are the main diagnostic tests of NARDL analysis. The probability values for the serial correlation results for all the models are greater than a 0.05 level of significance, authenticating the validity and reliability of the results. Likewise, the blue rays in the Cusum, and Cusum of squares results for all the models lie within the bootstrap area at a 95 percent confidence interval, signifying that the models are stable. In addition, the heteroscedasticity (Breusch-Pagan-Godfrey) test ensures that the variances of our models are constant, as a varying variance can invalidate the test of significance because the standard errors become biased, as well as the inference. However, the diagnostic test results for these analyses show that the disturbance errors for all the models are homoscedastic, having constant variance at a ≥0.05 significant level. This means the residuals of the analyses do not suffer from serial correlation, heteroscedasticity, or model misspecification errors. Finally, the lower section holds the results of the Wald's tests for the null hypothesis of no short-run and long-run asymmetry. Although three levels of significance are shown in this study, inferences are drawn based on a 0.05 level of significance.

TABLE 7 Results of Nonlinear ARDL Models

Variable	Short-run coefficients			Variable	Short-run coefficients		
	(1)	(2)	(3)		(1)	(2)	(3)
C	−0.78***	0.16	6.83**	D(IR_NEG(−2))		−0.02**	
D(LNFP(−1))	0.51***			D(IR_NEG(−3))		−0.02***	
D(LNFP(−2))	−0.22			D(LNFP_POS)		0.11	
D(LNEXR(−1))		0.17		D(LNFP_POS(−1))		−0.41**	
IR(−1)			0.73***	D(LNFP_POS(−2))		−0.71***	
D(LNEXR_POS)	−0.02		3.01***	D(LNFP_POS(−3))		−0.24	
D(LNEXR_POS(−1))	−0.14***		−1.70*	D(LNFP_NEG)		−1.25	
D(LNEXR_NEG)	0.74			D(LNFP_NEG(−1))		3.49	
D(LNEXR_NEG(−1))	0.21			D(LNFP_NEG(−2))		4.47	
D(LNEXR_NEG(−2))	0.86			D(LNFP_NEG(−3))		3.36	
D(LNCC_POS)	—	−2.18		D(LNMS)	0.13	−0.01	
D(LNCC_POS(−1))		10.55		D(LNMS(−1))	0.00	0.01***	
D(LNCC_POS(−2))		12.18**		D(LNMS(−2))	−0.29***	0.01***	
D(LNCC_POS(−3))		8.17**		D(TO)		0.01**	0.97
D(LNCC_NEG)		8.74*		D(TO(−1))		0.53***	1.38*
D(LNCC_NEG(−1))		18.52***		D(TO(−2))		−0.67**	
D(LNCC_NEG(−2))		9.43**		D(TO(−3))		−0.88***	
D(IR_POS)	−0.02**	−0.02		D(DM1)	0.46***	1.52***	8.07***
D(IR_POS(−1))	−0.01*	−0.01		D(DM1(−1))	0.41***	0.16	
D(IR_POS(−2))	−0.02**	−0.02		D(DM1(−2))		0.24	
D(IR_NEG)		−0.02***		D(DM2)	0.04		
D(IR_NEG(−1))		−0.01					

Continued on the next page

LONG-RUN AND SHORT-RUN NONLINEAR ARDL ANALYSIS

Results of Models 1–3

The results in table 7 reveal that there is a dynamic nonlinear relationship between climate change and macro prices (food prices and exchange rate, and climate change and exchange rate in the short run). Also, these nonlinear links exist for climate change and all the macro prices (food prices, exchange rate, interest rate) investigated in this study, in the long run, although not all are significant. These results are not unexpected and the results are thoroughly discussed in this section.

The short-run results of the NARDL reveal the outcomes of the positive and the negative shocks of regressors to exchange rate. Model 1 in the short run shows that increase in exchange rate reduces food prices

TABLE 7 *Continued from the previous page*

Variable	Long-run coefficients			Variable	Long-run coefficients		
	(1)	(2)	(3)		(1)	(2)	(3)
LNCC_POS	−2.66	−23.30	−53.61	LNFP_NEG		−4.34	7.91
LNCC_NEG	−2.91	−27.79**	−18.93	LNMS(−1)	0.91***		
IR_POS	−0.08	0.02		TO	−0.01*	−0.03***	−1.29
IR_NEG	0.06**	−0.05***		DM1(−1)	0.75***	2.90***	−9.96***
LNEXR_POS	0.72***		1.54	DM2(−1)	−0.48*	0.92**	−8.45***
LNEXR_NEG	2.33		1.51	ECT(−1)	−0.34***	−0.54***	−0.73***
LNFP_POS		−0.15	3.49				

Test	Diagnostics results		
	(1)	(2)	(3)
Breusch-Godfrey LM serial correlation test	0.06	0.14	0.39
Breusch-Pagan-Godfrey heteroscedasticity test	0.40	0.62	0.16
Ramsey Reset functional form and misspecification error test	0.58	0.93	0.87
CUSUM & CUSUM	≤ 0.05	≤ 0.05	≤ 0.05
Jarque-Bera	(0.84)	(0.37)	(0.12)

NOTES Column headings are as follows: (1) model 1, (2) model 2, (3) model 3. Models are defined by the dependent variables.

by 0.14%, suggesting that a domestic increase in food prices might not be due to exchange rate premium pass-through effects as submitted by the African Development Bank. However, as exchange rate falls in the long run, food prices reduce, confirming Nigeria's reliance on importation of food. These results also support theoretical literature on interest rate-saving behaviour. A unit increase in interest rate increases food prices by 3.49% while a decline in interest rate engenders a 7.91% decrease in food prices. This result suggests the presence of supply-side shocks resulting in increases/decreases in cost of borrowing for investment and eventual increase/decrease in food prices; however, the result is not significant at a 95% confidence interval. The result also corroborates the work of Durevall, Loening, and Ayalew Birru (2013) and the monetarists' view that a decrease in money supply increases the interest rate, reduces investment in food production, and hence engenders a hike in food prices. This is observed in the continuous rise in food prices in Nigeria, given the efforts of the Central Bank of Nigeria in tightening the monetary policy rate to improve the value of the naira. Climate change is not significant in explaining food prices in both the short run and long run but the direction of its movement with food prices is expected, as climate change increases food prices, and the fall in climate change still reveals an increase in food prices. This is because the damage caused by climate change could take years to reverse, coupled with the fact that Nigeria is more reliant on crude oil than agriculture. Moreover, the value chain development system employed in Nigeria is not anchored by natives; hence, policies submitted still benefit importation, rather than building the real sector.

For Model 2, the exchange rate model, the results show that positive shocks to climate change increase the amount of naira that is exchanged for a unit of dollar. Specifically, the units of naira that will be exchanged for a dollar will increase by an average of 10.55% to 12.18 %. In the same vein, as climate change falls, the amount of naira that is exchanged for a unit of dollar decreases; this is a positive causal effect, as the outcome moves in the same direction as the climate variable (a unit decline in LNCC reduces the units of naira that can be exchanged for dollars by 8.74% and 18.52% over time, respectively). In the same vein, reversing the effect of climate change in the long run could be slow; therefore a fall in climate change still shows an increase of 27.79% in the amount of naira exchanged for a dollar in Nigeria. This suggests that global warming reduces exports and foreign exchange earnings. This result agrees with Batten, Sowerbutts, and Tanaka (2020) and Feyen et al. (2020). Also, a unit fall in interest rate discourages capital inflow by 0.02% in the short run and 0.05% in the long run. Furthermore, the results corroborate the fact that a rise in prices weakens exchange rate – a one percentage point increase in food prices reduces exchange rate by 0.71%. This suggests that an increase in food prices devalues domestic currency, as the higher the rate of rise in prices, the faster the exchange rate pass-through effect (this result is equally the same in the long run). This agrees with Olamide, Ogujiuba, and Maredza (2022). Finally, international trade improves foreign exchange earnings and this is a consensus in economic research.

Lastly, the direction of the short-run results of Model 3 for exchange rate and trade follows the results in Model 2; however, all coefficients of the decomposition are insignificant in explaining interest rate in Nigeria. This suggests the relationship between the regressors and interest rate could be indirect. This is in line with Mckibbin et al. (2017), who revealed that the effect of climate change on interest rate is mostly the upshot of the carbon emissions policies engaged to mitigate the consequences of climate change.

In conclusion, the error correction terms (ECTS) of 0.34, 0.54 and 0.73 for Models 1, 2 and 3 are negative and significant at the 0.05 level, as well as

TABLE 8 Results of Wald and Multiplier Graphs for Model 1

(1)	(2)	(3)	(4)	(5)	(6)
Model 1 (food prices)	LNCC	—	0.49	—	Evidence of long-run symmetry
	IR	—	0.04**	—	Evidence of asymmetry in the long run
	LNEXR	0.03**	0.69	0.07*	Evidence of short-run asymmetry and long-run symmetry
Model 2 (exchange rate)	LNCC	0.29	0.60	0.09*	Evidence of short-run and long-run symmetry
	IR	—	0.03**	—	Evidence of long-run asymmetry
	LNFP	0.00***	0.50	0.00***	Evidence of asymmetry in the short run and symmetry in the long run
Model 3 (interest rate)	LNCC	—	0.45	—	Evidence of symmetry in the long run, climate change did not appear in the short run
	LNFP	—	0.92	—	Evidence of symmetry in the long run while food prices did not appear in the short run
	LNEXR	—	1.00	—	Evidence of symmetry in the long run, exchange rate did not appear in the short run

NOTES Column headings are as follows: (1) model, (2) variable, (3) short-run probability, (4) long-run probability, (5) joint probability, (5) conclusion. Null Hypothesis: No short and long-run asymmetry. ***, **, and, * represent levels of significance at 1%, 5%, and 10%, respectively.

less than 1, authenticating that long-run relationships exist among these variables. This means that 34%, 54% and 73% of disequilibrium errors in the previous year for each model are corrected in the current year.

Furthermore, table 8, which holds Wald's tests of asymmetry results, equally confirms that an asymmetric relationship exists between food prices and all the positive and negative long-run regressors (LNEXR, IR, LNCC), both in the short run and long run, except for the IR model in Wald's results. Furthermore, only exchange rate in Model 1, and climate change and food prices in Model 2, show joint asymmetric relationships (see table 8).

Relative Effects of Climate Change on Macro Prices

The beta coefficient measures the changes in the macro prices (food prices, exchange rate, and interest rate) that correspond to a unit change in the climate variable, holding other explanatory variables constant and

TABLE 9 Relative Effects of Climate Change on Macro Prices

Series	LNCC	$\dot{\beta}$
LNFP	−2.46(0.01/2.92)	−0.008*
IR	3.01(0.01/5.19)	0.006
LNEXR	1.18(0.01/2.45)	0.005

NOTES * significance at 10%.

measuring all changes in standard deviation units. This helps to determine the relative effects of the outcome from the different explanatory variables, as we employ Equation (16).

$$\dot{\beta} = \hat{\beta}\frac{S_x}{S_y}, \tag{16}$$

where $\dot{\beta}$ is beta coefficient, $\hat{\beta}$ is estimated beta, S_x is standard deviation of xth explanatory variable, and S_y is standard deviation of the dependent variable.

Given the fact that the long-run error correction results have shown that climate change has a significant impact on macro prices for all the models, then following the absolute values, the results show that the beta coefficient of 0.008 for food prices is the only significant coefficient at a 95% confidence interval. This confirms that climate has a major influence on food prices among the macro prices. Its influence on exchange rate is the least at 0.005. This corroborates the fact that climate change is not only an environmental challenge (Foye 2014) but also a monetary challenge now, being a source of financial risk. Hence, it is very important to reduce human-induced climate change and its consequences to stabilise the financial sector.

DISCUSSION OF RESULTS

The study employs nonlinear ARDL in validating that most macro variables are essentially nonlinear in three models of different macro prices (food prices, exchange rate, and interest rate), meaning that positive and negative factors of macro prices influence one another (Shin, Yu, and Greenwood-Nimmo 2014). Furthermore, the study determines the relative effects of climate change on these macro prices. Before the regression analysis, I took the log of the variables that are not in rates to ensure the data are normally distributed and for easy interpretation of results (see Ogun 2021; Wooldridge 2018). All the unit root tests (with or without structural breaks) reveal that all variables are all stationary at first difference I(1). To be precise, the NARDL unit root test reveals that all the variables are not stationary. Furthermore, cointegration of variables is established, using the NARDL bounds tests for the three models. The results for the models are significant at a 95% confidence interval with *F*-statistics of 5.28, 6.56, and 7.07 which are greater than the Pesaran, Shin, and Smith (2001) critical values, respectively. I proceed to analyse both the error correction model and the long-run NARDL, as advanced by Shin, Yu, and Greenwood-Nimmo (2014). Before drawing inferences, the validity of the models is established through different diagnostic tests: serial correlation, heteroscedasticity, and model specification. The probability values of all the tests are found to be greater than the 0.05 level, confirming the validity and the reliability of the models. Also, the cumulative sum (CUSUM) and its squares (CUSUM2) are significant at a 95 percent confidence interval, confirming the structural stability of the models.

The error correction terms for all Models 1–3 are −0.34, −0.54, and −0.73, respectively. These values are all significant at less than the 0.05 level, authenticating the bounds tests results. The error correction terms suggest that the speed of adjustment of a short-run disequilibrium for each model to its long-run equilibrium is 34%, 54%, and 73%, respectively. Models 1 and 2 with food prices and exchange rate as their dependent variables, respectively, reject the null of no long-run and short-run asymmetry, in that order, for IR and EXR, and for IR and FP, respectively, at the 0.05 level of significance. This suggests evidence of asymmetry, meaning that the models are best analysed using nonlinear ARDL. On the other hand, the results for Model 3 with interest rate as its dependent variable accept the null of no long-run and short-run asymmetry. This indicates that Model 3 is best analysed using a linear model which is a suggestion for further studies. Using the Wald test, asymmetry is equally confirmed in Models 1 and 2 for the macro prices employed alternatively in the long run and short run, except for the CC variable which exhibits pure symmetry both in the short and the long run. The third model, with interest rate as a dependent variable, also shows evidence of symmetry for both food prices and exchange rate, suggesting that interest rate has a linear influence on climate change, food prices, and exchange rate.

The results of the first model (relationship between food prices and climate change) is incongruous with the studies by Food and Agriculture Organisation of the United Nations (2019a), Hendrix and Haggard (2015), Kreidenweis et al. (2016), and Stevanović et al. (2016) that show climate change increases food prices in the long run. This might be as a result of Nigeria's reliance on imported foods. In addition, the literature has shown that trade openness is a buffer to reduced food prices; results in this study have shown that trade openness has initial positive impacts on the exchange rate until later when it starts to depreciate the domestic currency, suggesting that the over-reliance on oil at the expense of real sector growth remains a challenge in Nigeria. Despite the restriction on some food crops to build domestic food production, the impacts of climate change and the monoculture nature of Nigeria keep having negative consequences on macro prices in Nigeria. Furthermore, climate change reveals a positive impact on exchange rate in Nigeria, suggesting that the drive for growth, given the stage of development in Nigeria and its over-reliance on fossil fuels, might hinder mitigation efforts. This result agrees with Lee et al. (2021) in the short run and also with the results of Batten, Sowerbutts, and Tanaka (2020) and Feyen et al. (2020) in the long run, as a fall in climate change engenders increased exchange rate. Hence, the need to encourage consistent and continuous climate mitigation is germane in avoiding the volatility of macro prices. Finally, neither the negative nor the positive factors of climate change, exchange rate, and food prices have significant effects on interest rate in Nigeria, suggesting that the relationship between climate change and interest rate is policy driven.

In all, the results in this study suggest the continual need for a green economy (renewable energy sources and other energy-efficient technologies) to combat climate change in the pursuit of macro-financial growth in Nigeria.

Conclusion and Policy Implications

This paper reveals very reliable estimates for food prices, exchange rate, and interest rate in relation to climate change in Nigeria by departing from the studies that employed integrated assessment results which gives assumed estimates (Tol 2006). Also, the study employs the appropriate model, a nonlinear ARDL model, in the analysis of nonlinear macro prices. However, the study reveals the fact that interest rate performs more efficiently in a linear model in the long run, given that the results rejected the null hypothesis of asymmetry. Hence, the interest rate model is symmetrical and therefore can be analysed by employing a linear model. Most importantly, the study reveals that contemporaneous LNFP moves in tandem with EXR in the short run while contemporaneous positive and negative LNCC moves in the same and opposite direction with food prices in the long run, respectively, though not significantly. This suggests that it is only concerted and consistent mitigation strategies that can engender a green economy that favours lower food prices. On the other hand, an increase in IR reduces food prices, and an increase in money supply makes food prices affordable; however, the lag and long-run response of food prices agree with both theory and *a priori* expectations. The implication of this is that undertaking policy initiatives and strategies based on symmetry could be inadequate, given the fact that asymmetry allows for other effective alternatives in policy engagements. Furthermore, climate change did not show asymmetry in its relationship with exchange rate in the long run although asymmetry is observed in the short-run lags; as expected, IR shows a positive relationship with the exchange rate, as domestic currency appreciates as a result of capital inflow from the rest of the world. Finally, as trade expands in the short run, the exchange rate appreciates marginally; however, it falls in the long run. Obviously, this is expected and the implication is clear, as overreliance on fossil fuel remains a battle begging to be overcome in Nigeria. Hence, this paper concludes that a dynamic relationship exists between macro prices and climate change in Nigeria, underscoring the importance of prompt redesigning of macroeconomic policies to capture climate change for growth and sustainable development.

This study recommends that the Nigerian government and policymakers should ratify and pursue policy initiatives and strategies based on asymmetry for climate change, food prices and exchange rate. As regards the negative influence of climate change on macro prices, Nigeria should begin to carry out a mitigation and vulnerability analysis in both the financial and real sectors to forestall the negative consequences of climate change. Furthermore, the country needs a total embrace of green technologies, technology transfer and specialisation through trade interactions to encourage green growth. The mitigation process should not only be the transition of Nigeria from fossil fuel use but also the gradual end of exporting oil to other countries which in effect is a way of encouraging burning of fossil fuels in other countries. In fact, it cannot be overemphasised that Nigeria now needs to rely more on robotic green technology to protect the financial sector from uncertainties. Moreover, the real sector needs to be revived to improve on foreign exchange earnings. In effect, Nigeria needs natives, and not non-natives, to develop its value chain development system if its agricultural sector will ever resuscitate the manufacturing sector for healthy growth and stability of the financial and real sectors. In addition, since climate change is a global phenomenon and Nigeria is one of the most vulnerable populations, the government should mandate foreign partners to equally adopt green technologies. Finally, the submission of an interim report by Nigeria in May 2021 is a good step in the right direction. This means Nigeria is beginning to build environmentally friendly structures to keep the country on the path of sustainable growth and development.

References

Abidoye, B. O., and A. F. Odusola. 2015. 'Climate Change and Economic Growth in Africa: An Econometric Analysis.' *Journal of African Economies* 24 (2): 277–301.

Ackerman, F., S. J. DeCanio, R. B. Howarth, and K. Sheeran. 2009 'Limitations of Integrated Assessment Models of Climate Change.' *Climatic Change* 95 (3): 297–315.

Adedeji, A. O., and V. O. Foye. 2019. 'Macro Prices, National Economic Growth and Unemployment in Nigeria.' In *Faculty of Management Sciences Conference Proceedings,* 1–15. Ojo: Lagos State University.

Allen, D., and M. McAleer. 2021. 'A Nonlinear Autoregressive Distributed Lag (NARDL) Analysis of the FTSE and S&P500 Indexes.' *Risks* 9 (11): 195. https://doi.org/10.3390/risks9110195.

Arshad, S., and A. Ali. 2016. 'Trade-off between Inflation, Interest and Unemployment Rate of Pakistan: Revisited.' MPRA Paper 78101, University Library of Munich, Munich.

Aye, G. C., and R. F. Haruna. 2018. 'Effect of Climate Change on Crop Productivity and Prices in Benue State, Nigeria.' In *Establishing Food Security and Alternatives to International Trade in Emerging Economies,* edited by V. Erokhin, 244–68. Hershey, PA: IGI Global.

Bai, J., and P. Perron. 2003. 'Computation and Analysis of Multiple Structural Change Models.' *Journal of Applied Econometrics* 18 (1): 1–22.

Bandara, J. S., and Y. Cai. 2014. 'The Impact of Climate Change on Food Crop Productivity, Food Prices and Food Security in South Asia.' *Economic Analysis and Policy* 44 (4): 451–65.

Barguellil, A., O. Ben-Salha, and M. Zmami. 2018. 'Exchange Rate Volatility and Economic Growth.' *Journal of Economic Integration* 33 (2): 1302–36.

Bates, D. M., and D. G. Watts. 2007. *Nonlinear Regression Analysis and Its Applications.* New York: Wiley.

Batten, S., R. Sowerbutts, and M. Tanaka. 2020. 'Climate Change: Macroeconomic Impact and Implications for Monetary Policy.' In *Ecological, Societal, and Technological Risks and the Financial Sector,* edited by T. Walker, D. Gramlich, M. Bitar, and P. Fardnia, 13–38. Cham: Palgrave Macmillan.

Bauer, M. D., and G. D. Rudebusch. 2021. 'The Rising Cost of Climate Change: Evidence from the Bond Market.' Federal Reserve Bank of San Francisco Working Paper 2020–25, Federal Reserve Bank of San Francisco, San Francisco.

Bhalia, N. 2021. 'Climate Change Threatens Kenyan Tea Sector, Putting Millions of Workers at Risk.' World Economic Forum. May 17. https://www.weforum.org/agenda/2021/05/climate-change-is-threatening-kenya-black-tea-industry/.

Bofinger, P, and M. Ries. 2017. 'Excess Saving and Low Interest Rates: Theory and Empirical Evidence.' CEPR Discussion Paper 12111, Centre for Economic Policy Research, London.

Bradbear, C., and S. Friel. 2013. 'Integrating Climate Change, Food Prices and Population Health.' *Food Policy* 43:56–66.

Bylund, E., and M. Jonsson. 2020. 'How Does Climate Change Affect the Long-Run Real Interest Rate?' Economic Commentaries No. 11, Sveriges Riksbank, Stockholm.

CBN. 2020. Central Bank of Nigeria Statistical Bulletin.

Cheung, A. H., M. E. Mann, B. A. Steinman, L. M. Frankcombe, M. H. England, and S. K. Miller. 2017. 'Comparison of Low-Frequency Internal Climate Variability in CMIP5 Models and Observations.' *Journal of Climate* 30 (12): 4763–76.

Cosmas, N. C., I. Chitedze, and K. A. Mourad. 2019. 'An Econometric Analysis of the Macroeconomic Determinants of Carbon Dioxide Emissions in Nigeria.' *Science of the Total Environment* 675:313–24.

Durevall, D., J. L. Loening, and Y. Ayalew Birru. 2013. 'Inflation Dynamics and Food Prices in Ethiopia.' *Journal of Development Economics* 104:89–106.

Fankhauser, S., and R. S. J. Tol. 2005 'On Climate Change and Economic Growth.' *Resource and Energy Economics* 27 (1): 1–17.

Fankhauser, S., J. B. Smith, and R. S. J. Tol. 1999. 'Weathering Climate Change. Some Simple Rules to Guide Adaptation Investments.' *Ecological Economics* 30 (1): 67–78.

Feldstein, M., and O. Eckstein. 1970. 'The Fundamental Determinants of the Interest Rates.' *The Review of Economics and Statistics* 52 (4): 363–75.

Feyen, E., R. Utz, I. Zuccardi Huertas, O. Bogdan, and J. Moon. 2020. 'Macro-Financial Aspects of Climate Change.' Policy Research Working Paper 9109, World Bank, Washington, DC.

Food and Agriculture Organisation of the United Nations. 2016. *The State of Food and Agriculture: Climate Change, Agriculture and Food Security.* Rome: Food and Agriculture Organisation of the United Nations.

———. 2019a. *Agriculture and Climate Change: Challenges and Opportu-*

nities at the Global and Local Level; Collaboration on Climate-Smart Agriculture. Rome: Food and Agriculture Organisation of the United Nations.

———. 2019b. *The State of Food Security and Nutrition in the World 2019: Safeguarding against Economic Slowdowns and Downturns.* Rome: Food and Agriculture Organisation of the United Nations.

———. 2021. *The State of Food Security and Nutrition in the World 2021: Transforming Food Systems for Food Security, Improved Nutrition and Affordable Healthy Diets for All.* Rome: Food and Agriculture Organisation of the United Nations.

Foye, V. O. 2014. 'Climate Change: Human Health and Economic Growth in Nigeria.' PhD diss., Obafemi Awolowo University.

———. 2018. 'Dynamics of Climate Change, Human Health and Economic Growth: Evidence from Nigeria.' *African Journal of Sustainable Development* 8 (2): 31–62.

———. 2020. 'Impacts of Population and Climate Change on Sustainable Development in Nigeria.' https://ic-sd.org/wp-content/uploads/2020/10/Victoria-Foye_Proceedings.pdf.

Foye, V. O., and O. O. Benjamin. 2021. 'Climate Change, Technology and Manufacturing Sector Growth in Oil-Rich Nigeria.' *International Journal of Sustainable Economy* 13 (3): 236–60.

Foye, V. O., A. O. Adedeji, and M. A. Babatunde. 2020. 'A Nonlinear Analysis of Trade, Foreign Direct Investment and Carbon Dioxide Emissions in Nigeria.' https://doi.org/10.13140/RG.2.2.19078.70725.

Frankel, J. A. 2007. 'On the Rand: Determinants of the South African Exchange Rate.' *South African Journal of Economics* 75 (3): 425–41.

———. 2014. 'Effects of Speculations and Interest Rate on in a "Carry Trade" Model of Commodity Prices.' *Journal of International Money and Finance* 42:88–112.

Galindo, L. M., O. Reyes, and J. E. Alatorre. 2015. 'Climate Change, Irrigation and Agricultural Activities in Mexico: A Ricardian Analysis with Panel Data.' *Journal of Development and Agricultural Economics* 7 (7): 262–73.

Graff Zivin, J. S., S. Hsiang, and M. Neidell. 2018. 'Temperature and Human Capital in the Short- and Long-Run.' *Journal of the Association of Environmental and Resource Economists* 5 (1): 77–105.

Güriş, B. 2017. 'A New Nonlinear Unit Root Test with Fourier Function.' MPRA Paper 83080, Munich Personal REPEC Archive, Munich.

Haug, A. A., and M. Ucal. 2019. 'The Role of Trade and FDI for CO_2 Emissions in Turkey: Nonlinear Relationships.' *Energy Economics* 81:297–307.

Hendrix, C. S., and S. Haggard. 2015. 'Global Food Prices, Regime Type, and Urban Unrest in the Developing World.' *Journal of Peace Research* 52 (2): 143–57.

Hepsag, A. 2017. 'New Unit Root Tests with Two Smooth Breaks and Nonlinear Adjustment.' MPRA Paper 83353, Munich Personal REPEC Archive, Munich.

Holmes, A., B. Illowsky, and S. Dean. 2017. *Introductory Business Statistics.* Houston, TX: OpenStax.

Howard, P., and T. Sterner. 2014. 'Raising the Temperature on Food Prices: Climate Change, Food Security, and the Social Cost of Carbon.' Paper presented at the Agricultural & Applied Economics Association's 2014 AAEA Annual Meeting, Minneapolis, MN, July 27–29. https://ageconsearch.umn.edu/record/170648.

Huh. H.-S., and C.-Y. Park. 2013. 'Examining the Determinants of Food Prices in Developing Asia.' ADB Economics Working Paper Series 370, Asian Development Bank, Mandaluyong.

Igbokwe-Ibeto, C. J. 2019. 'Climate Change, Food Security and Sustainable Human Development in Nigeria: A Critical Reflection.' *Africa's Public Service Delivery and Performance Review* 7 (1): a322. https://doi.org/10.4102/apsdpr.v7i1.322.

Iheoma, C. 2014. 'Impact of Climate Change on Agricultural Production and Sustainability in Nigeria.' *Asian Journal of Agricultural Extension, Economics and Sociology* 4 (1): 29–41.

Inim, V., U. E. Samuel, and A. I. Prince. 2020. 'Other Determinants of Inflation in Nigeria.' *European Journal of Sustainable Development* 9 (2): 338–48.

IPCC. N.d. 'Frequently Asked Questions.' IPCC Sixth Assessment Report. https://www.ipcc.ch/report/ar6/wg2/about/frequently-asked-questions/

Iyke, B. N., and S.-Y. Ho. 2017. 'Nonlinear Effects of Exchange Rate Changes on the South African Bilateral Trade Balance.' *The Journal of International Trade and Economic Development* 27 (3): 350–63.

Kapetanios, G., Y. Shin, Y., and A. Snell. 2003. 'Testing for a Unit Root in the Nonlinear STAR framework.' *Journal of Econometrics* 112 (2): 359–79.

Kiley, M. T. 2021. 'Growth at Risk from Climate Change.' Finance and Economics Discussion Series 2021-054, Board of Governors of the Federal Reserve System, Washington, DC.

Kreidenweis, U., F. Humpenöder, M. Stevanović, B. L. Bodirsky, E. Kriegler, H. Lotze-Campen, and A. Popp. 2016. 'Afforestation to Mitigate Climate Change: Impacts on Food Prices under Consideration of Albedo Effects.' *Environmental Research Letters* 11 (8): 085001. https://doi.org/10.1088/1748-9326/11/8/085001.

Kruse, R. 2011. 'A New Unit Root Test against ESTAR Based on a Class of Modified Statistics.' *Statistical Papers* 52 (1): 71–85.

Lee, S., N. Mark, J. Nauerz, J. Rawls, and Z. Wei. 2021. 'Global Temperature Shocks and Real Exchange Rates'. https://www.jonasnauerz.com/publication/climate_change/Climate_change.pdf

Mckibbin, W., A. Morris, A. Panton, and P. Wilcoxen. 2017. 'Climate Change and Monetary Policy: Dealing with Disruption.' CAMA Working Paper 77, Crawford School of Public Policy, Centre for Applied Macroeconomic Analysis, The Australian National University, Canberra.

Monfared, S. S., and F. Akın. 2017. 'The Relationship between Exchange Rates and Food Prices: The Case of IRAN.' *European Journal of Sustainable Development* 6 (4): 329–40.

NASA: Global Climate Change; Vital Signs of the Planet. N.d. 'Overview: Weather, Global Warming and Climate Change.' https://climate.nasa.gov/resources/global-warming-vs-climate-change/

Nisbet, R., G. Miner, and K. Yale. 2018. *Handbook of Statistical Analysis and Data Mining Applications.* 2nd ed. London: Elsevier Academic Press.

Nusair, S. A. 2016. 'The Effects of Oil Price Shocks on the Economies of the Gulf Co-Operation Council Countries: Nonlinear Analysis.' *Energy Policy* 91:256–67.

Ogbuabor, J., A. Orji, C. O. Manasseh, and O. Anthony Orji. 2020. 'Climate Change and Agricultural Output in the ECOWAS Region.' *International Journal of Sustainable Economy* 12 (4): 403–14.

Ogun, O. D. 2021. 'Two Observations in the Application of Logarithm Theory and Their Implications for Economic Modeling and Analysis.' *Mathematics and Statistics* 9 (3): 218–24.

Okoye, L. U., F. O. Olokoyo, F. N. Ezeji, J. I. Okoh, and G. O. Evbuomwan. 2019. 'Determinants of Behavior of Inflation Rate in Nigeria.' *Investment Management and Financial Innovations* 16 (2): 25–36.

Olamide, E., K. Ogujiuba, and A. Maredza. 2022. 'Exchange Rate Volatility, Inflation and Economic Growth in Developing Countries: Panel Data Approach for SADC.' *Economies* 10 (3): 67. https://doi.org/10.3390/economies10030067.

Pesaran, M. H. 1997. 'The Role of Economic Theory in Modelling The Long Run.' *The Economic Journal* 107 (440): 178–91.

Pesaran, M. H., and Y. Shin. 1999. 'An Autoregressive Distributed Lag Modelling Approach to Cointegration Analysis.' In *Econometrics and Economic Theory in the 20th Century, the Ragnar Frisch Centennial Symposium,* edited by S. Strøm, 371–413. Cambridge: Cambridge University Press.

Pesaran M. H., Y. Shin Y., and R. J. Smith. 2001. 'Bounds Testing Approaches to the Analysis of Level Relationships.' *Journal of Applied Econometrics* 16 (3): 289–326.

Raleigh, C., H. J. Choi, and D. Kniveton. 2015. 'The Devil Is in the Details: An Investigation of the Relationships between Conflict, Food Price and Climate across Africa.' *Global Environmental Change* 32:187–99.

Rudebusch, G. D. 2021. 'Climate Change Is a Source of Financial Risk.' *FRBSF Economic Letter* 3:1–6.

Shin, Y., B. C. Yu, and M. Greenwood-Nimmo. 2014. 'Modelling Asymmetric Cointegration and Dynamic Multipliers in a Nonlinear ARDL framework.' In *Festschrift in Honor of Peter Schmidt,* edited by R. C. Sickels, and W. C. Horrace, 281–314. New York: Springer.

Shuaibu, M. 2020. 'Impact of Trade Openness and Climate Change on Food Productivity in Nigeria.' *Foreign Trade Review* 56 (2): 165–84.

Stevanović, M., A. Popp, B. L. Bodirsky, F. Humpenöder, C. Müller, I. Weindl, and X. Wang. 2016. 'Mitigation Strategies for Greenhouse Gas Emissions from Agriculture and Land-Use Change: Consequences for Food Prices.' *Environmental Science and Technology* 51 (1): 365–74.

Tanure, T. M. do P., D. N. Miyajima, A. S. Magalhães, E. P. Domingues, and T. S. Carvalho. 2020. 'The Impacts of Climate Change on Agricultural Production, Land Use and Economy of the Legal Amazon Region Between 2030 and 2049.' *Economia* 21 (1): 73–90.

The World Bank. N.d. 'World Development Indicators.' https://databank.worldbank.org/source/world-development-indicators.

Tol, R. S. J. 2006. 'Exchange Rates and Climate Change: An Application of Fund.' *Climatic Change* 75 (1–2): 59–80.

Tumwine, S., S. Sejjaaka, E. Bbaale, and N. Kamukama. 2018. 'Determinants of Interest Rate in Emerging Markets.' *World Journal of Entrepreneurship, Management and Sustainable Development* 14 (3): 267–90.

United States Environmental Protection Agency. N.d.a. 'Climate Change: Basic Information.' https://19january2017snapshot.epa.gov/climatechange/climate-change-basic-information_.html.

———. N.d.b. 'Climate Change Indicators: Weather and Climate.' https://www.epa.gov/climate-indicators/weather-climate.

———. N.d.c. 'Overview of Greenhouse Gases.' https://www.epa.gov/ghgemissions/overview-greenhouse-gases.

Wooldridge, J. M. 2019. *Introductory Econometrics: A Modern Approach.* 7th Edition. Boston, MA: Cengage Learning.

Yeo, S. R., and K. Y. Kim. 2014. 'Global Warming, Low-Frequency Variability, and Biennial Oscillation: An Attempt to Understand the Physical Mechanisms Driving Major ENSO Events.' *Climate Dynamics* 43 (3–4): 771–86.

Zhang, P., O. Deschenes, K. Meng, and J. Zhang. 2018. 'Temperature Effects on Productivity and Factor Reallocation: Evidence from a Half-Million Chinese Manufacturing Plants.' *Journal of Environmental Economics and Management* 88:1–17.