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Dynamics of coffee output in Nigeria

Dinâmica da produção de café na Nigéria

Ndubuisi Chigozirim Onwusiribe[1], Jude Anayochukwu Mbanasor[1], Ogbannaya Ukeh Oteh[2]

[1] Michael Okpara University of Agriculture, Department of Agribusiness and Management, Umudike, Abia State, Nigeria. E-mail: onwusiribe.chigozirim@mouau.edu.ng; mbanasor.jude@mouau.edu.ng

[2] Michael Okpara University of Agriculture, Department of Marketing, Umudike, Abia State, Nigeria. E-mail: oteh.ogbonnaya@mouau.edu.ng

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Abstract: Coffee is a strategic cash crop for poverty reduction and economic growth in Nigeria, and it is consumed worldwide, making it a significant source of income at both the micro and macro levels. This study analysed the trends in ' 'Nigeria's coffee output and the short and long-run determinants of coffee output in Nigeria. A period of 38 years was considered and the data were sourced from the Food and Agriculture Organization, the World Bank and the International Coffee Organization. The linear trend and the Autoregressive Distributed Lag Model were instrumental in the data analysis. The trend analysis reveals that coffee output is decreasing, necessitating immediate action. Fertiliser use and land availability for farmers require extra attention in the short run because they are significant and had a positive impact on coffee output. In the long-run climate change, producer price and fertiliser use negatively impact the coffee farmers' output. The need to make land easily accessible to coffee farmers by amending land use regulations to ensure the conservation and expansion of farmlands is one of the most notable recommendations of this study.

Keywords: Coffee; Output; Dynamics; Price; Climate; Land.

Resumo: O café é uma cultura comercial estratégica para a redução da pobreza e o crescimento econômico na Nigéria, e é consumido em todo o mundo, tornando-se uma fonte significativa de renda nos níveis micro e macro. Este estudo analisou as tendências na produção de café da Nigéria e os determinantes de curto e longo prazo da produção de café na Nigéria. Foi considerado um período de 38 anos e os dados foram obtidos da Organização para a Alimentação e Agricultura, o Banco Mundial e a Organização Internacional do Café. A tendência linear e o Modelo Autorregressivo de Atraso Distribuído foram instrumentais na análise dos dados. A análise de tendências revela que a produção de café está diminuindo, exigindo ação imediata. O uso de fertilizantes e a disponibilidade de terras para os cafeicultores exigem atenção extra no curto prazo porque foram significativos e tiveram um impacto positivo na produção de café. No longo prazo, as mudanças climáticas, o preço ao produtor e o uso de fertilizantes têm um impacto negativo na produção dos cafeicultores. A necessidade de tornar a terra facilmente acessível aos cafeicultores por meio de emendas aos regulamentos de uso da terra para garantir a conservação e a expansão das terras agrícolas é uma das recomendações mais notáveis deste estudo.

Palavras-chave: Café; Produção; Dinâmica; Preço; Clima; Terra.

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1 Introduction

Nigeria is the focus of this research. Nigeria is located in West Africa, between latitudes 4° and 14° north and longitudes $2°2^{1}$ and $14°30^{1}$ east. Nigeria has a land area of around 923,769 km^2, although only about half of it is currently cultivated. In 2019, the land area utilised for coffee growing was expected to be 10 km^2, whereas in 1981, the land area used for coffee farming was 60 km^2. Agriculture in Nigeria is mainly influenced by the weather, with possible irrigation areas ranging from 1.5 to 3.2 million hectares.

Coffee (*Coffee arabica and Robusta coffee*) is a popular beverage and a significant source of income for actors along the coffee value chain in Nigeria, as well as a valuable cash crop for enhanced export earnings (Akinpelu et al., 2021; Alli et al., 2021; Mohammed et al., 2013; ICC, 2015; Krishnan, 2017). The coffee tree is a perennial woody tree crop. *Coffee* is a shade-loving tree that thrives in the shadow and is well-known for helping to preserve the ecology (Akinpelu et al., 2021). The coffee berry or cherries contain the seeds, often known as coffee beans. Processed coffee beans are raw materials for making coffee beverages (Singh & Verma, 2017; Esquivel & Jiménez, 2012). The coffee plant is indigenous to Africa, with its origins linked to Ethiopia, Central Africa, and West Africa (Ayoola et al., 2012; ICC, 2015). Coffee grows between the latitudes of 25°N and 25°S, but commercial growing requires peculiar environmental conditions (Ogundeji et al., 2019). Coffee is mainly produced by millions of small-scale farmers in the tropics; the coffee-producing states in Nigeria include Bauchi, Kwara, Plateau, Taraba, Cross River, and Osun; however, there are also temperate zones in Nigeria that can support coffee production. Coffee farming is a significant employer of labour; it is estimated that 9 million farmers are employed in the coffee value chain in Nigeria (ICC, 2015). Nigeria's low coffee output is due to a combination of factors, including poor farming practices, low mechanisation, limited access to funding and inputs, and the effects of the climate (PwC, 2017; Mohammed et al., 2013; Ayoola et al., 2012). Every day, almost 500 billion cups of coffee are drunk globally (Czarniecka-Skubina et al., 2021). It is produced and eaten as a beverage by individuals of all ages, particularly the active population, due to its energising, anti-inflammatory, and antioxidant benefits (Ayoola et al., 2012; Sousa et al., 2016; Rehm et al., 2020).

Temperature, rainfall, sunlight, wind, and soils are crucial in coffee production, but the needs vary depending on the cultivated varieties (Ayoola et al., 2012). The changing climate in the tropics, particularly in terms of altered rainfall patterns and extended dry spells in most parts of Nigeria, has led to soil water balance changes, flooding, drying up of water bodies, and desert encroachment. Due to delayed rainfall in some of the producing regions, coffee production in Nigeria is expected to decline in the 2020/21 farming season (Bjornlund et al., 2020; Malhi et al., 2021). In addition, the increase in the incidence of pests and diseases that harm the coffee tree, such as parasitic nematode, coffee berry borer, leaf rust, coffee berry disease, brown eyespot, and coffee wilt disease, is linked to climate variations (Gizaw et al., 2021; Ogundeji et al., 2019). These conditions impact the productivity of most small-scale coffee farmers, lowering their income.

Coffee output in Nigeria has declined due to population growth, which has caused producers to convert their farms to residential areas, resulting in a shortage of suitable land (ICC, 2009; Ogundeji et al., 2019). The majority of small-scale coffee producers are abandoning their farms due to climate change and production issues outside the farmers' control. Most coffee farms are old and unprofitable, and the farmers have abandoned traditional farming practices (Aderolu et al., 2014). Longer drought spells and interrupted flowering cycles are two examples of climate change impacts on coffee, resulting in decreased quantity and quality of coffee harvested (Gizaw et al., 2021; Ogundeji et al., 2019). Coffee will go extinct unless suitable climate change mitigation and adaptation methods are implemented, which include conservation, monitoring, and seed preservation (Ogundeji et al., 2019; Duke & Cornell, 2019). According to Kollipara (2014), the issue of global warming and other climate change effects must be treated as an emergency, or the land area suitable for coffee farming will decline by 50%, affecting global coffee output. In addition, coffee farmers suffer low output quality, low harvest pricing, insufficient processing and storage facilities, and unreliable marketing channels. Given the importance of coffee worldwide, output in Nigeria has been declining in past decades. Low prices on the international market, limited access to production factors, and the effects of climate change posed the most significant challenge. For example, in 1966, Nigeria produced 4000 tonnes of coffee, but in 1967, it only produced 1712 tonnes due to political unrest that hindered access to production assets. In 1969, Nigeria produced 4776 tonnes of coffee, whereas, in 1979, Nigeria produced 3200 tonnes. Recently in 2019, the output of coffee was 1117, which declined from 2400 tonnes recorded in 2010 (FAO, 2021).

Land, capital, output and input prices, and climatic factors are all important factors influencing the short run and long run coffee production (Nchare, 2007). These factors make small-scale coffee farmers more vulnerable to postharvest losses of more than 50% (Kasso & Bekele, 2018; Baca et al., 2014). Because there are few locations where coffee production can thrive sustainably, the choice of location for coffee production has further limited access to land (Tosh, 1980). The development of the coffee value chain has been hampered by low levels of technological adoption and the labour-intensive nature of the coffee processing. As a result, low-quality coffee beans are produced, which do not command the same competitive price as coffee beans from other countries (Idrisu et al., 2012). The use of standard cultural practices and other standardisation practices will allow coffee farmers to produce efficiently and meet the demands of the international coffee market (Tollens, 2002). This persistent fluctuation in the output of an important cash crop such as coffee is problematic. Therefore, there is a need to seek empirical evidence of the short-run and long-run dynamics of coffee output in Nigeria.

The broad objective of this study is to analyse the dynamics of coffee output in Nigeria. The specific objectives are to analyse the linear trend of coffee output in Nigeria and the short-run and long-run determinants of coffee output in Nigeria. Coffee production shows the influence of production factors and macroeconomic variables in determining the rate of acceleration and deceleration, stability and stagnation of coffee production during the time frame under consideration (Onwumere et al., 2021; Ikeno, 2007; Ababu & Getahun, 2021). Some authors have argued that the interplay of economic variables when determining the short- and long-term performance of a product cannot be overlooked because of the influence of time (Davis et al., 2012; Robinson et al., 2020; Gizaw, 2021; Wasihun, 2019; Ayele et al., 2021). This is because the way economic variables interact with one another is affected by the passage of time. Short and long-term fluctuations in coffee's short and long-term trends may be influenced by significant production and climate factors in economies with relatively simple and small economies (Cervantes-Godoy et al., 2014; Ahmed et al., 2021; Gizaw et al., 2021). An evaluation of the next decade's trend in coffee production must take into account production variables and climate and extraneous influences (Ahmed et al., 2021; Ogundeji et al., 2019; Oko-Isu et al., 2019).

2 Literature review

Ethiopians are the first to drink coffee, a tradition that dates back to the country's colonial history (Orlowska, 2013). There are two African varieties of coffee: Arabica and Robusta. In contrast to Robusta coffee, Arabica coffee is grown at higher altitudes, often on volcanic soils. Compared to Robusta, Arabica is more difficult and expensive to grow. Building nurseries, planting, maintaining, and harvesting mature beans are all part of the first phase in the coffee value chain (primary phase in the value chain) (van Asten et al., 2011). Phase two involves the postharvest processing of fully mature beans. Wet or dry processing can significantly impact a product's value. Marketing and packaging are part of phase three. Roasting and distribution are included in the fourth section. Only a few exporting countries, and even fewer in Africa, reach this value chain stage (ICC, 2015). Small-holders dominate coffee farming in almost all African countries, ranging from half a hectare to ten hectares. Large plantations of coffee estates are rare in Nigeria (Karanja, 2002). Except in Malawi and Zambia, estates dominate coffee farming. Estate farms produce 40% of Kenya's total output. The number of active coffee farmers in Africa is estimated to be between 10 and 12 million (Moyo, 2016; Dinham& Hines, 1984). The total number of coffee-growing households is estimated at seven million, with an average household size of two adults (ICC, 2015).

There is a dearth of literature on coffee production in Nigeria. Akinpelu et al. (2021) investigated the factors that influence coffee marketing by small-scale producers in Nigeria. The authors used the double log regression model to analyse the data. Education of the producers, farm size, coffee variety, and experience were all critical factors. While conducting a similar study to Akinpelu et al. (2021), Idrisu et al. (2012) reported that coffee is grown by 25 to 30 million small-holder producers in the tropics. The authors used a qualitative approach to discuss the unique challenges to coffee production in Nigeria, such as the abolition of the marketing board, a lack of an appropriate quality control system, adulterated coffee beans, a poor information system for the dissemination of coffee technology, a lack of incentives, and a lack of farm inputs. Ayoola et al. (2012) investigated the factors that limit coffee production and sales. Diseases, pests, land, capital, labor, poor technology, and global prices are constraints.

Nchare (2007) identified land inputs, coffee tree age, experience, and capital as factors influencing the technical efficiency of Cameroonian Arabic coffee producers. Boansi & Crentsil (2013) used the unit root test and OLS regression. The authors looked at coffee yield, producer price, world price, nominal rate, competitiveness, and labour as factors influencing coffee production.

Machuka (2016) investigated the determinants of coffee farm productivity in Kenya, focusing on coffee farm size, fertilisers, chemicals, prices, and costs. The Cobb-Douglas approach was used to analyse the data, and a sample of 125 farmers was studied. Jaramillo et al. (2013) investigated the impact of Global Environmental Change (GEC) on coffee production in East Africa, including climate change and variability and urbanisation. The study used spatial and demographic data over 80 years. Verter et al. (2015) found that price is a significant determinant of coffee production using multiple regression analysis on a 17-year data set when analysing the production and export of coffee in Uganda. Harris et al. (2012) used the Autoregressive Integrated Moving Average (ARIMA) time series model on a 20-year data set to study coffee production in Ghana. According to the findings, coffee production in Ghana has been steadily increasing. Okoisu et al. (2019) used the Fully Modified OLS model to estimate the impact of climate change, price, and other factors on coffee production in Nigeria, emphasising the importance of price as a production determinant. Hordofa (2021) used the Autoregressive distributed Lag Model to analyse the determinants of Ethiopian coffee exports and found that the quantity of coffee produced is critical for export performance. It is essential to justify the choice of variables that are included in the ARDL model. The first is temperature as a determinant of coffee output in Nigeria. Climate constraints in Nigeria are dominated by high temperatures (Haider, 2019). Due to climate change and the expansion of coffee cultivation to marginal lands, such as in Nigeria's north, these constraints are expected to grow in importance in several coffee-growing regions (Grüter et al., 2022; Pereira, 2017). Poor weather and a lack of water are limiting coffee production. Restrictions on physiology and thus yields of *Coffee arabica* and *Coffee canephora*, which account for nearly all of the world's coffee bean production, have been found by DaMatta & Ramalho (2006). Kath et al (2021) and Legesse (2019) reported that increased temperature above 22 °C increases the risk of poor coffee yield.

The second determinant of coffee output in Nigeria is the price of coffee. The price of coffee is not immune to inflationary pressures, especially with the collapse of the International Coffee Agreement (ICA) and the liberalisation of markets which made the forces of demand and supply determine price (Mkandya et al., 2010). The price of coffee is correlated to inflationary pressures, the higher the level of inflation the price of coffee goes higher and vice versa (Paul, 1994), and Coffee market prices have fluctuated over time. Coffee is distinguished by a combination of short periods of high and volatile prices and long periods of low and stable prices. Coffee passes through many hands from whole green bean to coffee cup, and different price levels emerge along the value chain. Producer price increases were primarily caused by agricultural, climatic, and environmental risks. Weather has played a significant role in explaining price volatility (Li, 2016; Ssenkaaba, 2019). The impact of positive and negative shocks on coffee price return volatility has long-lasting and asymmetrical, affecting coffee markets (Swaray, 2007). Coffee export earnings are increasing dramatically as coffee prices rise on the global market, and export earnings could be increased further by increasing produced quantities and improving coffee quality to meet the requirements of international markets (Talbot, 1997; Al-Abdulkader et al., 2018). Local markets pay higher prices for coffee than export markets, averaging $7.45 thousand per ton versus $1.98 thousand (Al-Abdulkader et al., 2018). Coffee prices are volatile due to seasonality, inelastic demand, production uncertainty, and coffee export prices are determined on international markets (Lewin et al., 2004). Coffee Price fluctuations represent a significant price risk, and they are closely related to inflation. In the absence of a hedging mechanism, increased volatility in coffee prices increases uncertainty about future prices (Yovo, 2021).

Based on some literature, the availability of suitable land for coffee production is a determinant of coffee output. Cleland (2010) reported that after 15 years' time, most small scale coffee farmers convert their land to staple crop and livestock farms thereby depleting the quantity of land available for coffee production. Sachs et al. (2019) estimate that by 2050, 75 percent of suitable land for coffee production will have been lost. There have been rapid and significant biophysical changes on coffee farmland in the last two decades due to low coffee prices, changing climate, severe plant pathogen outbreaks, and other factors (Harvey et al., 2021). The access to capital by the coffee farmers in Nigeria is a determinant of output. Minh et al. (2016) reported that capital is a significant factor affecting the productivity of coffee farmers and Bukuru & Tabitha (2021) also noted that capital has a positive correlation coefficient with the production of coffee farmers in Burundi. Providing a long-term source of financing for coffee value chains has been a challenge because of poor contractual and product quality issues (Fitter & Kaplinksy, 2001). There are still several small-holder coffee farmers who lack resources and capital. Through low-cost credit, new processing technologies can only be made available to farmers outside of the project and to other regions (Markelova et al., 2009). Farmers require a large amount of capital to maximise the use of coffee production technology.

The availability of capital is expected to boost coffee production and productivity, thereby improving farmers' well-being (Valkila, 2009). Access refers to a coffee farmer's ability to obtain capital and finance services from a bank or financial institution, either individually or in groups (Milder, 2008). A farmer has access to a specific credit source as long as they can get loans from that credit source, though they may choose not to ask for a loan for various reasons.

The neoclassical theory requires three factors for production to increase, and labor, capital, and technological innovation drive production. According to neoclassical growth theory, these three factors are not critical to achieving long-term equilibrium, all things being equal (Knight et al., 1993). The total output is determined by coffee producers' capital and labour (Volsi et al., 2019; Miller & Upadhyay, 2000). Improvements in inputs and technology on Nigeria's labour-intensive coffee farms could boost output (Nolte & Ostermeier, 2017; Fuglie & Rada, 2013).

These factors are critical to the growth of coffee. Solow and Swan developed the neoclassical growth theory in 1956. The foundation of ARDL is Neoclassical Growth Theory, which has been the standard model for predicting long-run production (Asghar et al., 2020; Sakyi, 2011; Adeyemi & Ogunsola, 2016; Yusuf & Mohd, 2021; Growiec et al., 2018; Rumanzi et al., 2021). According to the neoclassical theory of growth, capital, labour, and technology must all be in appropriate proportions. Before this can happen, the scale of the capital, labour, and technology involved in producing more coffee needs to be adjusted, long-term equilibrium does not take any of these three factors into account. The theory emphasises the interaction of the various factors involved in coffee production.

3 Materials and methods

The Food and Agriculture Organization (FAO) database, the World Bank's World Development Indicators (WDI), the Central Bank of Nigeria statistical bulletin, and the International Coffee Organization (ICO) are the sources of data analysed, which spanned the years 1981 to 2019 (see Appendix A); while the Auto-Regressive Distributed Lag (ARDL) model regression approach for the data analysis.

3.1 The ADF test for Unit root test

The ADF test consist of estimating the following regression:

$$\Delta Y_t = \beta_1 + \beta_1 + \delta Y_{t-1} + \Sigma^{m}{}_{t} = 1 \propto_i \Delta Y_{t-1} + e_t \quad (1)$$

The null hypothesis is δ=0 versus δ<o (thus, expansive negative estimations of the test measurements prompt the dismissal of the invalid), and Δ is the difference operator.

The alternative requires that Yt be differed to achieve stationarity; the alternative does not require that Yt be differed because it is already stationary (Dickey & Fuller, 1981).

3.2 The Auto-Regressive Distributed Lag model

According to Pesaran et al. (2001), the estimate of the Auto-regressive Distributed Lag (ARDL) model, also known as the bounds testing approach to cointegration, was used to investigate the dynamics of coffee output and climate change in Nigeria. The ARDL is used on time series data with integration orders of I (0) and I (1) (i.e. mixed order of integration) to generate an unbiased long-run estimate where a long-run connection exists (Bawa et al., 2016; Udoh et al., 2015; Labibah et al., 2021). The fundamental justification for using an ARDL model must be provided by an underlying economic theory or model, such as the neoclassical growth model. If the dependent variable must remain constant over time, the lags of the dependent variable and explanatory variables (The AR components) must be included (Shrestha & Bhatta, 2018; Okafor & Shaibu, 2016). Other explanatory variables' lags must be included because they can have a long-term impact. Suppose the explanatory variables are stationary and there are enough observations. In that case, OLS standard coefficient estimates can be used because the correlation matrix of these explanatory variables (including lags) tends to be a positive-definite matrix as the number of observations increases and exogenetic conditions are met.

The first step in ARDL testing is to ensure that there is an optimal number of lags between I(1) and I(0) using the Akaike Information Criterion (AIC) or a Schwarze Bayesian Criterion (SBC). In the ARDL model, it is critical to ensure no endogeneity issues by ensuring that the lag structure is both optimal and sufficient (see Appendix B). To test the validity of the cointegration, the error correction model must be negative, indicating that exogenous variables and computed t-values return to long-run equilibrium levels. The unit root tests can be used to validate the constant mean and variance of time series (Tinoco-Zermeno et al., 2014). In the ARDL model, a combination of I(0) and I(1) is the best way to integrate variables, but not when a variable is integrated I(1) (2). According to ARDL, when I(0) and I(1) are met, the model provides more accurate estimates, and the F-statistics of the bound test show a long-term relationship between the variables. Because there is only one co-integrating vector, the ARDL model is best suited for this analysis. Due to its robustness and excellent performance with a sample size of 40, the ARDL model is selected (Latif et al., 2015). The ARDL model can produce asymptotically normal estimates of the long-run coefficients regardless of whether the underlying regressors are integrated at level and first difference (Pesaran & Shin, 1995). When some economic variables are taken into account and policy recommendations are required, the ARDL model plays a critical role (Nkoro & Uko, 2016).We estimated the model as follows.

$$output = c_o + \delta_1 output_{t-1} + \delta_2 temperature_{t-1} + \delta_3 price_{t-1} + \delta_4 land_{t-1} + \delta_5 fertilizer_{t-1} + \delta_6 capital_{t-1} + \sum_{i=1}^{p4} b_1 output_{t-1} + \sum_{i=0}^{p} b_2 temperature_{t-1} + \sum_{i=0}^{p1} b_3 price_{t-1} + \sum_{i=0}^{p4} b_4 land_{t-1} + \sum_{i=0}^{p} b_5 fertilizer_{t-1} + \sum_{i=0}^{p} b_6 capital_{t-1} + \varepsilon_t \quad (2)$$

Where δ_i refers for long-run multipliers, c_o represents constant, ε_t is the error term and bi for coefficients. The lag duration is p, and the error term is t. The ARDL bound test following Equation 1 to test for the existence of a long-run relationship.

the ARDL bound test was done following Equation 1 to test for the existence of a long-run relationship. We tested the following hypotheses.
H_0 = the long-run multipliers are not significantly different from zero ($H_0 = \delta_1=\delta_2=\delta_3=\delta_4=\delta_5=\delta_6=0$)
H_a= the long-run multipliers are significantly different from zero ($H_a= \delta_1\neq\delta_2\neq\delta_3\neq\delta_4\neq \delta_5\neq\delta_6 0$)

The bound test shows that there is long-run relationship existing between the variables, this is because the F-calculated value did not fall within or equal to the tabulated values. It implies that long and short-run relationships exist.

The long-run dynamic parameters are derived by estimating the model (2)

$$output = c_o + \sum_{i=1}^{p1} b_1 output_{t-1} + \sum_{i=0}^{p} b_2 temperature_{t-1} + \sum_{i=0}^{p} b_3 price_{t-1} + \sum_{i=0}^{p1} b_4 land_{t-1} + \sum_{i=0}^{p1} b_5 fertilizer_{t-1} + \sum_{i=0}^{p} b_6 capital_{t-1} + \mu_t \quad (3)$$

The short-run dynamic parameters are derived by estimating the error correction model

$$\Delta output = c_o + \sum_{i=1}^{p1} b_1 \Delta output_{t-1} + \sum_{i=0}^{p} b_2 \Delta temperature_{t-1} + \sum_{i=0}^{p} b_3 \Delta price_{t-1} + \sum_{i=0}^{p1} b_4 \Delta land_{t-1} + \sum_{i=0}^{p1} b_5 \Delta fertilizer_{t-1} + \sum_{i=0}^{p} b_6 \Delta capital_{t-1} + \vartheta ecm_{t-1} \quad (4)$$

Where ECM is the error correction term of Equation 3 and ϑ is the speed of adjustment. We define the other symbols in the equations:
Output= Coffee output (tonnes)
Temperature = temperature change (°C)
price = producer price of coffee (₦)
Land = Area of land harvested (ha)
Fertiliser = Fertiliser consumption (kilograms per hectare of arable land)
capital = Recurrent Expenditure on agriculture (₦)
Δ= Difference operator
$\sum$ = summation sign

4 Results and discussion

Table 1 shows the results of the unit root test using Augmented Dickey-Fuller, which demonstrated that the variables under examination are stationary at the level and first difference. The presence of unit roots in the data suggests that shocks have a long or short term impact (Labibah et al., 2021).

Table 1. Unit root test Augmented Dickey Fuller.

Variables	Level	First difference	Decision
output	-2.950	-7.908	I(1)
Temperature	-5.457	-8.470	I(0)
Price	-2.745	-6.012	I(1)
Land	-4.600	-8.160	I(0)
Fertilizer	-1.401	-7.096	I(1)
capital	-5.506	-6.977	I(0)

Note: The Augmented Dickey Fuller unit root test was done with trend and constant and lag length of 9.

Figure 1 shows the trend in Nigerian coffee production from 1981 to 2019, as well as a 10-year prediction. The coffee production from 1981 to 2019 shows a decreasing trend. In 1981, Nigerian coffee output was 3000 tonnes, but it peaked at 6000 tonnes in 1984 and then plummeted to 1200 tonnes in 1985. This tendency was also seen in Latin America and other coffee-producing countries (Lewin et al., 2004; Akpan et al., 2012). Since 1986, the trend in output has been fluctuating, with a declining pattern since 2012; Alli et al. (2021) also found a downward trend in coffee output from Nigeria since 2012. Based on a 10-year forecast, the trend-line reveals that coffee output in Nigeria would decline, consistent with Lewin et al.'s findings (2014). From 2010 to 2014, diseases such as coffee berry disease, coffee wilt, and root-rot disease devastated many coffee farms worldwide, contributing to a decline in coffee production. The impact of climate change has been prominent in causing the decline, with erratic rainfall and changing temperatures in coffee-producing areas causing the decline.

The government established the Agricultural Development Program (ADP), which was critical in growing crops such as coffee. Due to a drop in oil prices that began in 1982, there were insufficient funds to complete the projects, resulting in delays and reduced coffee production (Ambali & Murana, 2017). Another reason for the decline in coffee production is that ADP emphasises modern, high-input techniques such as sole cropping, whereas most farmers still use mixed or relay cropping methods (Ofana et al. 2016). The late 1990s and early 2000s in Nigeria were marked by trade liberalisation, and this era boosted coffee production, particularly from 1995 to 2007. (Soule, 2013). From 2010 to 2015, there was an effort to increase commitment to the production of staple crops at the expense of traditional cash crops such as coffee, which was pushed by the Comprehensive Africa Agricultural Development Program (CAADP). Coffee production fell significantly from 2010 to 2019 (Hallam & Willebois, 2013).Recently, the country's coffee production has decreased. In 2007, Nigerian farmers produced 5340 tonnes of coffee, but this number dropped by more than 70% in 2018. Small-scale farmers in developing countries like Nigeria, who lack adequate technical education and face low market prices, have poor management, low productivity and abandoned farms (D'Haese et al., 2004; Alli et al., 2021). As the price of coffee has dropped, many small-scale farmers have been discouraged from producing it, resulting in a drop in coffee production in Nigeria. For local coffee farmers in Nigeria, the lack of a national coffee policy is a major issue (Ayoola et al., 2012; Sachs et al., 2019). The national policy framework developed by Nigeria, the National Tea and Coffee development Council, is not fully implemented. Even the largest coffee companies in the country use beans from other countries to make instant coffee, which is still not widely consumed in the country (Oniku & Akintimehin, 2021; Pelupessy, 2007). The lack of commitment of large coffee companies has harmed the entire value chain (Lewin et al., 2004).

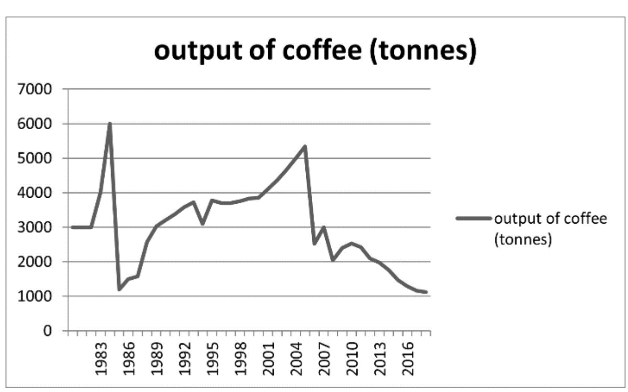

Figure 1. The trend in Nigerian coffee production.

The bound test presented in Table 2 reveals that the variables have a long-run relationship, necessitating the estimate of an ARDL model. The F-statistics value of 1.465 is more than both the lower and upper I(0) bounds.

Table 2. ARDL Bound Test.

Test Statistic	**Value**	**k**
F-statistic	1.465	5
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	2.26	3.35
5%	2.62	3.79
2.5%	2.96	4.18
1%	3.41	4.68

Table 3 shows the short-run and long-run ARDL model estimates from Equation 4 for the dynamics of coffee output and climate change. In the short run, land was statistically significant at 1% and had a positive coefficient in the long run. This result implies that the access to land by the coffee farmers led to the increase in the quantity of coffee produced in the short-run, which is applicable in the long-run because of the importance of land in the cultivation of coffee. According to Mohammed et al. (2013) and Degaga (2020), the size of the land used in coffee farming has a significant impact on the output of coffee. This is because the amount of other inputs to be used is dependent on the size of the land utilised. There are significant areas of land in Nigeria where coffee can be grown; states such as Taraba, Abia, Kogi, Kwara, and Ogun have a significant land mass for commercial coffee production, and the area harvested of coffee in 2018 was 1483ha (Alli et al., 2021). Despite the vast amount of land available for coffee production and an estimated 200000 small-holder coffee farmers in Nigeria, Nigerian coffee's contribution to global production has remained negligible (ICC, 2015).

Postharvest losses account for a large portion of Nigerian coffee production by small-scale farmers. Most of Nigeria's coffee is grown by small-holders on a few hectares (Alli et al., 2021). reports have confirmed the heavy toll on coffee farmers, who have been forced to sell below cost or abandon their farms because current prices do not cover harvesting and transportation costs (ICC, 2015; Lewin et al., 2004). The state of insecurity and sociopolitical tension has limited access to small scale coffee farms; there have been reports of violent insurgency, attacks, kidnapping, communal conflicts, banditry, and rape in farmlands in coffee-producing areas, resulting in a contraction of coffee production and marketing (Bjornlund et al., 2022; Onwusiribe et al., 2015; Kimenyi et al., 2014; Amalu, 2015). Land ownership laws, legislation, cultural and tribal beliefs all limit access to large areas of land suitable for coffee production. In Nigeria, all land belongs to the government, and bureaucratic bottlenecks in the land acquisition process are a significant impediment for coffee producers who want to devolve into large-scale coffee production (Oluwatayo et al., 2019). The coffee industry is characterised by many small farmers who have no formal relationships with buyers, making synergy in land use for mechanisation extremely difficult.

In the short run, fertiliser use was positive and significant at 10%, and the coefficient is negative in the long run. The use of fertiliser by Nigerian coffee farmers results in an increase in the quantity of coffee produced in the short-run. However, the continuous application of fertiliser in the soil without proper soil management practices results in the reduction in the output of coffee farmers. According to Ayegboyin et al. (2015), fertiliser fertiliser application significantly improves soil aeration, soil structure, soil microorganisms, and water penetration, resulting in increased coffee yield. However, the unregulated use of fertiliser over a long period of time diminishes the soil quality. The preservation of soil organic matter is central to coffee production in Nigeria, and the use of NPK fertiliser in coffee farms has been shown to increase the intake of essential nutrient elements such as Ca, Mg, Cu, and others (Ayegboyin et al., 2015). Organic fertiliser application improves soil microorganism activity, soil structure, aeration, and water penetration (Ngaruiya, 1995). The long-run coefficient is negative because coffee soils leach nutrients, resulting in low organic matter content and the need for careful management to support crop yield (Dawid, 2018). The proper management of coffee farm soil to improve organic matter content is critical for the long-term sustainability of small scale coffee farms in Nigeria to increase coffee output (Lal, 1987). Nigeria has implemented various fertiliser subsidy regimes, resulting in a short-term increase in coffee production (Alabi & Adams, 2015; Michael et al., 2018). Continuous application of inorganic fertiliser reduces long-term coffee output. There have been instances where coffee farmers were unable to obtain subsidised fertilisers, resulting in a significant decrease in coffee output (Lewin et al., 2004).

The coefficient for temperature change was negative in the short and long run, implying that persistent climate change influences coffee production in the short and long term. According to Okoisu et al. (2019), climate change has resulted in a decrease in the amount of coffee produced in Nigeria. Many coffee-growing countries have seen their output fluctuate due to temperature changes. The real changes in where and how coffee is grown are expected as a result of global warming (Gokavi & Kishor, 2020). According to scientists, one of the world's most popular beverages may become extinct if conservation and monitoring measures are not implemented (Davis et al., 2012; Feria-Morales, 2002; Castillo et al., 2020). The quality of coffee decreases as the temperature rises, making coffee plants sensitive to microclimate changes (Ogundeji et al., 2019). While temperatures of 23 °C or higher can hasten fruit ripening and reduce product quality, temperatures of 18-21 °C are ideal for optimum growth and flavour (Ogundeji et al., 2019). Because microclimate changes affect coffee quality, coffee plants are susceptible to them. Temperatures of 18-21 °C are ideal for fruit growth and flavour, while temperatures of 23 °C or higher can hasten to ripen and reduce product quality (Poltronieri & Rossi, 2016).

Climate data can help coffee farmers improve their risk management framework. Local demand for climate information must be identified to achieve this goal, and coffee yield relationships with climate variables, farmer perceptions, and local cocoa farmer actions must be investigated (Pons et al., 2021; Edet et al., 2018).

The price of coffee has a negative coefficient in both the short and long run, meaning that the price of coffee is not competitive or fair to Nigerian coffee farmers. Coffee price has a negative elasticity (average yearly supply shift) with coffee supply (output), according to Ssenkaaba (2019). Boansi & Crentsil (2013), on the other hand, found that producer price had a positive impact on the quantity of coffee produced by Ethiopian farmers; the authors concluded that Ethiopian coffee is of high quality and hence fairly priced. Prices on the coffee market have been volatile. Arabica declines by 3% per year, while robusta declines by 5% (Ssenkaaba, 2019). Production increases as new lower-cost producers enter the market, export prices rise, and a cycle of renewable planting and innovation follows price spikes (Christensen, 2016). Coffee demand and supply have always been influenced by price. The price is determined by supply and demand. For a sustainable coffee economy, producers should be paid competitive prices that cover production, living, and environmental costs, according to the International Coffee Committee (ICC) (Sachs et al., 2019; ICC, 2015). Coffee bean prices fluctuate because neither supply nor demand is constant. Given that supply shifts have more positive and negative shifts, supply shifts have a greater influence on coffee price fluctuations than demand shifts (Ssenkaaba, 2019). Because Nigeria's economy is so reliant on oil exports, fluctuations in oil prices have a greater impact on coffee prices in Nigeria than anywhere else (Gylych et al., 2020; Abdlaziz et al., 2018). This is not the case with other major coffee-producing countries.

The agricultural goods market alternates between high prices with high volatility and low prices with low volatility, and coffee is typical (IMF, 2011). When coffee prices are low, farmers invest less. Climate change, pests and diseases, limited land and insufficient inputs, equipment, and market information all impact coffee supply and price.

In both the short and long term, capital spent on agriculture over the time studied had a negative coefficient, meaning that capital expenditure on agriculture in Nigeria was insufficient and not used efficiently for coffee production (see Table 3). Coffee farmers in Africa are cash-strapped due to a lack of credit and a high-risk assessment among lending institutions. Farmers do not have a well-diversified source of income, so they rely on their meagre personal savings to fund their coffee farms (AfDB, 2017).

Capital is an important factor in increasing coffee productivity. Capital is essential for purchasing equipment, knowledge, land, and research for sustainable coffee development. According to Bukuru and Tabitha, capital investment positively affects coffee output (2021). Coffee producers in Nigeria have long faced a slew of capital constraints, and many of these can be attributed to low or volatile coffee prices. There is a need to increase the upstream flow of credit, thereby catalysing new productivity-enhancing investments and contributing to more profitable and sustainable coffee farmer livelihoods (Parizat et al., 2015).

Table 3. ARDL Short-run and Long-run estimates.

Cointegrating Form				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D(Temperature)$_{-1}$	-222.895	238.650	-0.934	0.358
D(Price)$_{-1}$	-0.001	0.001	-0.508	0.615
D(Land)$_{-1}$	0.533	0.046	11.691	0.000
D(Fertilizer)$_{-1}$	47.565	26.059	1.825	0.079
D(Capital)$_{-1}$	-1.288	5.046	-0.255	0.801
CointEq(-1)	-0.095	0.095	-1.006	0.323
Cointeq = OUT - (-2342.904*TEMP -0.003*PRICE + 0.297*LAND				
-153.495*FERT -13.533*CAP + 6322.261)				
Long Run Coefficients				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
(Temperature)$_{-1}$	-2342.904	3644.924	-0.643	0.526
(Price)$_{-1}$	-0.003	0.006	-0.447	0.658
(Land)$_{-1}$	0.297	0.538	0.553	0.585
(Fertilizer)$_{-1}$	-153.495	200.837	-0.764	0.451
(Capital)$_{-1}$	-13.533	53.859	-0.251	0.803
C	6322.261	4806.731	1.3153	0.199

As shown in Table 4, the F-statistics value (0.525807) was statistically insignificant, implying that we accept the null hypothesis of no serial correlation in the ARDL model. The Breusch – Godfrey Correlation Lagrange Multiplier test produces probability values for F-statistics that are significant enough to reject the null hypothesis that there is no autocorrelation in the regression model residuals. We can conclude that the test is valid because it is not affected by serial correlation throughout the series.

Table 4. Breusch-Godfrey Serial Correlation LM Test.

F-statistic	0.525807	Prob. F(2,2)	0.6554
Obs*R-squared	11.71671	Prob. Chi-Square(2)	0.0029

Figure 2 shows the Cumulative Sum (CUSUM) Control Chart, which demonstrates the ARDL model's stability; the data are stable because the CUSUM graph is within the limits of the 5% significance level.

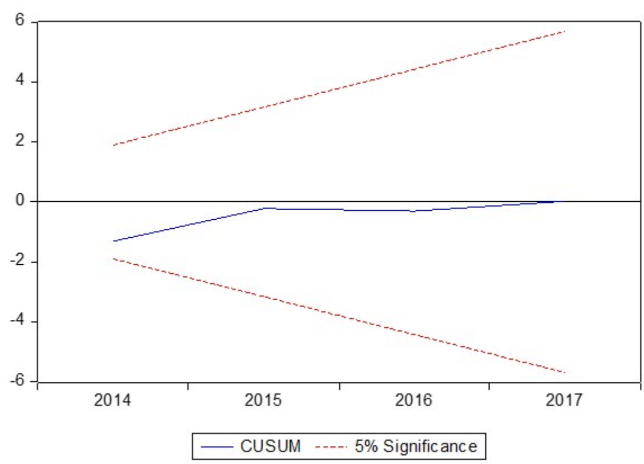

Figure 2. Cummulative Sum Control Chart.

5 Conclusion

The output of coffee in Nigeria has been declining, and the parameters examined in the ARDL model are critical in assessing the nature of the trend. In the short run, significant short-run factors such as land and fertiliser use are critical for coffee farmers' output to increase. In the long run, the usage of fertiliser has a negative impact on coffee farmers' output. Climate change, exacerbated by rising temperatures, has a short- and long-term negative impact on coffee farmers' output. The producer price of coffee has a negative short- and long-term impact on coffee farmers' output, meaning that the price of coffee is not fair enough to encourage them to produce more. Farmers' access to financing is restricted, as government funding has not resulted in an improvement in both short- and long-term coffee output. As a result, it is critical to make certain recommendations in order to avoid a predicted decline in coffee output.

There is a pressing need to encourage coffee farmers to embrace and adapt proven climate change mitigation strategies in order to slow the rate of temperature rises (global warming), which distorts the coffee production cycle and reduces accessible area for cultivation through desertification. Coffee farmers' associations and cooperative societies in coffee-growing regions should be at the forefront of disseminating information about climate change adaptation strategies. The recommendations on area for cultivation and climate change variables are because factors such as temperature and land have shortrun impact on coffee production. Price regulation through government policies is key in ensuring that coffee farmers obtain a fair price for their output; marketing board activation is also crucial in price regulation. It is critical to conserve farmland by amending land use laws to prevent it from being converted to residential areas.

There are some practical implications from the result of the study for producers and other stakeholders in the coffee food ecosystem. The result provides strong support for continue investment in coffee production but highlights obvious gaps in value chain acitivites in Nigeria and marketing issues. First, the decreasing trend in coffee production has negative impact on government desire to diversify Nigeria economy away from oil. This has severe implications for revenue, employment opportunities and the growth of Nigeria economy. Secondly, the importance of agricultural input materials like fertiliser provides direction for investment and scaling up of solutions around agricultural input services.

Given that government cannot address majority of these challenges, this study encourage the use of private-public partnership (PPP). This will reduce cost of procurement of input material and create economic opportunities. Thirdly, the significance of climate change and land issues emphasises the need to improve policies that address intelligent agricultural practices and review land use instruments that impede land ownership and access in Nigeria. There is a growing concern around climate change but it can be effective management with innovative and smart practices. However, this requires large investment and government support to mitigate risk. The risk of non-adherence to smart and innovative practices is higher.

Finally, the nexus between price and supply is not in doubt. With hgher price, there is the tendency to supply more. This requires development and invesmtnet in value chain activities, access to the market and management of supply chain networks. The reengineering of board must address two key fundamentals – creating demand from the consumer side, which will stimulate demand around innovative coffee market offerings, and connecting small scale resource coffee farmers to market with higher returns on their investment.

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Appendix A. Data set analyzed.

year	area harvested (ha)	output of coffee (tonnes)	producer price naira	Fertiliser (kilograms per hectare of arable land)	temperature change (centigrade)	credit to agriculture in naira ('000000)
1981	6000	3000	1155	12.9479	0.195	0.01
1982	6000	3000	1155	12.2189	0.377	0.01
1983	6000	3000	1255	14.8243	0.279	0.01
1984	8000	4000	1405	12.6762	0.82	0.02
1985	12000	6000	1450	9.67826	0.416	0.02
1986	2400	1200	4000	9.21393	0.552	0.02
1987	3000	1500	5500	8.43196	0.855	0.05
1988	3000	1570	6000	11.568	0.538	0.08
1989	3400	2570	7464	12.9557	-0.363	0.15
1990	3434	3030	6680	14.211	0.619	0.26
1991	3500	3200	8750	14.3067	0.653	0.21
1992	3600	3380	151667	14.6179	-0.085	0.46
1993	3700	3580	120000	15.3156	0.545	1.80
1994	4000	3720	74167	9.54839	0.471	1.18
1995	3122	3090	148000	5.56231	0.448	1.51
1996	3652	3780	135000	5.24169	0.789	1.82
1997	3444	3700	132500	4.14759	0.71	2.06
1998	3300	3700	70020	4.8	1.078	2.89
1999	3130	3750	65630	4.79143	0.812	59.32
2000	3190	3830	68610	5.35714	0.565	6.34
2001	3210	3850	67930	6.69697	0.249	7.06
2002	3330	4100	159497	4.52888	0.779	9.99
2003	3540	4360	185176	6.141	0.838	7.54
2004	3580	4660	307616	4.54511	0.757	11.30
2005	3670	4990	283622	7.19733	1.255	16.30
2006	3710	5340	357371	10.0389	1.283	17.92
2007	2000	2520	371661	4.20505	0.875	32.48
2008	2100	3000	292762	5.87683	0.631	65.40
2009	1800	2040	456231	5.26103	1.369	22.44
2010	1990	2400	745535	12.2137	1.492	28.22
2011	1942	2525	770003	6.56129	0.9	41.20
2012	1893	2417	510425	8.6687	0.577	33.30
2013	1639	2100	367621	9.01817	0.964	39.43
2014	1520	1972	590737	9.50187	1.048	36.70
2015	1345	1755	504867	8.45716	1.228	41.27
2016	1138	1466	793572	11.4072	1.214	36.30
2017	1002	1290	808981	21.06	1.19	50.26
2018	901	1161	688294	19.7373	1.069	53.99
2019	868	1117	899937		1.26	70.27

Variables	Source
area harvest	FAOSTAT
output	FAOSTAT
price (1981-2002)	FAOSTAT
price (2003-2019)	ICO
fertiliser	WDI
temperature	FAOSTAT
agriculture capital	CBN

Estimation command using Eviews

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ARDL(DEPLAGS=2, REGLAGS=2, IC=HQ) OUT TEMP PRICE LAND FERT CAP
@ @EXPAND(@MONTH,@DROPFIRST)
OUT = C(1)*OUT(-1) + C(2)*TEMP + C(3)*PRICE + C(4)*LAND + C(5)*LAND(-1) +
C(6)*FERT + C(7)*FERT(-1) + C(8)*CAP + C(9)
```

Appendix B. Lag selection criteria.

Model	LogL	AIC*	BIC	HQ	Adj. R-sq	Specification
2119	-248.686588	14.839234	15.328057	15.007975	0.920593	ARDL(1, 3, 0, 1, 1)
1994	-247.874445	14.849968	15.383230	15.034050	0.920898	ARDL(1, 4, 0, 1, 1)
1119	-249.377880	14.878736	15.367560	15.047478	0.917394	ARDL(3, 1, 0, 1, 1)
2118	-248.546633	14.888379	15.421641	15.072461	0.917801	ARDL(1, 3, 0, 1, 2)
1991	-245.555924	14.888910	15.555488	15.119012	0.920321	ARDL(1, 4, 0, 1, 4)
1494	-248.657920	14.894738	15.428001	15.078820	0.917277	ARDL(2, 3, 0, 1, 1)
1989	-247.659931	14.894853	15.472554	15.094275	0.918310	ARDL(1, 4, 0, 2, 1)
2114	-248.664986	14.895142	15.428404	15.079224	0.917243	ARDL(1, 3, 0, 2, 1)
2094	-248.677589	14.895862	15.429124	15.079944	0.917184	ARDL(1, 3, 1, 1, 1)
2116	-246.766599	14.900949	15.523088	15.115711	0.918679	ARDL(1, 3, 0, 1, 4)
1495	-249.781562	14.901804	15.390627	15.070545	0.915466	ARDL(2, 3, 0, 1, 0)
1369	-247.853313	14.905904	15.483604	15.105326	0.917403	ARDL(2, 4, 0, 1, 1)
1969	-247.870263	14.906872	15.484573	15.106294	0.917323	ARDL(1, 4, 1, 1, 1)
1993	-247.872338	14.906991	15.484691	15.106413	0.917313	ARDL(1, 4, 0, 1, 2)
1370	-249.125366	14.921449	15.454712	15.105532	0.915037	ARDL(2, 4, 0, 1, 0)
1114	-249.218962	14.926798	15.460060	15.110880	0.914582	ARDL(3, 1, 0, 2, 1)
494	-249.263707	14.929355	15.462617	15.113437	0.914363	ARDL(4, 1, 0, 1, 1)
1919	-246.268637	14.929636	15.596214	15.159739	0.917009	ARDL(1, 4, 3, 1, 1)
2120	-251.293278	14.931044	15.375430	15.084446	0.911526	ARDL(1, 3, 0, 1, 0)
994	-249.312479	14.932142	15.465404	15.116224	0.914124	ARDL(3, 2, 0, 1, 1)
1941	-244.346432	14.934082	15.689537	15.194865	0.917380	ARDL(1, 4, 2, 1, 4)
2044	-247.356718	14.934670	15.556809	15.149432	0.915890	ARDL(1, 3, 3, 1, 1)

*Selection criteria.