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Impact of Agricultural Production on Economic Growth in Zimbabwe

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To achieve inclusive growth, and poverty and inequality reduction, African countries should enhance labour-intensive agricultural production due to their abundance of natural resources and labour. In this paper, we examine the impact of agriculture on the economic growth of Zimbabwe using the Autoregressive Distributed Lag (ARDL) model employing data covering the period 1970 to 2019. The results show that agricultural production has a significant positive impact on economic growth in the short run while showing no impact on economic growth in the long run. Additionally, the study confirms that inflation, government expenditure and gross fixed capital formation have a positive impact on economic growth in both the long run and short run. Although the agricultural sector plays a salient role in the early stages of economic development, it is, however, not able to maintain sustainable economic growth over a long period in Zimbabwe. Additional macro-economic policy levers are required to compliment agricultural production and promote sustainable economic growth.

Key Words: agricultural production, economic growth, Autoregressive Distributed Lag Model
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Introduction

To recover the lost progress on their objective of achieving of inclusive growth, sub-Saharan African countries must strengthen the production of labour-intensive agricultural products. There is well-documented research supporting the viewpoint that agriculture production stimulates economic growth, and if this is indeed the case, African economies can specialise in agricultural production as a solution to end poverty and food insecurities. The abundance of various kinds of natural and human resources in African economies, including Zimbabwe, gives the countries an upper hand to strengthen their comparative advantage in agricultural products if these resources are used efficiently and effectively. With the promotion and expansion of intra-regional trade, developing countries like Zimbabwe may reap benefits from trading agricultural smart goods with other countries within Africa, thereby recovering the lost progress on sustainable development caused by the outbreak of the COVID-19 pandemic and previous political or economic shocks.

Zimbabwe has been facing pressing economic challenges for the past two decades and this has been aggravated by the COVID-19 pandemic. Like other developing African economies, Zimbabwe's economy is characterised by extreme poverty, high inequalities and hyperinflation. The World Bank (The World Bank Group 2022b) shows that the extreme poverty rate in Zimbabwe increased steadily between 2011 and 2020, although it declined in 2021: the poverty rate was 22% in 2011 and estimated to be 41% in 2021. Although poverty remains an overwhelmingly rural phenomenon, it has increased relatively faster in urban areas, leading to the urbanisation of poverty. Nevertheless, agricultural activity remains a major source of income and food for many families, particularly in rural areas, and has helped in creating better standards of living while reducing rural to urban migration.

Agriculture is the foundation of Zimbabwe's economic growth. According to World Bank Development Indicators (The World Bank Group 2022a), Zimbabwe's agriculture, forestry, and fishing value added as percentage of gross domestic product (GDP) was around 8.5% on average for the past decade. Although agriculture, forestry and fishing value added (% of GDP) has been declining over time, there is highly productive arable land in Zimbabwe which gives the nation an opportunity to stimulate growth through agriculture production. Given that these resources are continuously utilised efficiently to expand agricultural output, this may have a significant impact on economic growth. The economy rebound that happened in 2021 was driven by recovery of agriculture and industry. GDP is estimated to have grown by 5.8% in 2021 after contracting by 6.2% in 2020 (The World Bank Group 2022b). An exceptionally good agriculture season coupled with slowing inflation and higher remittances boosted domestic demand. However, over the past decade, several severe droughts and cyclones, such as the recent Cyclone Idai, which have occurred in Zimbabwe have contributed to the reduction in agricultural production as well as low economic growth, leading to high poverty and food insecurity. With the climate change effect, enhancing labour-intensive agriculture smart goods production can be crucial for a quicker economic recovery, employment creation and poverty alleviation.

The abundance of natural and human resources needed for agriculture in Zimbabwe raises debate on whether labour-intensive agriculture production should be used as an instrument for growth. To the best of our knowledge there is scant research about the impact of agriculture production on the economic growth of Zimbabwe. The main objective of this paper is to develop an econometric model, analysing the impact of agriculture production on economic growth. The research problem is to evaluate if agriculture production creates sustainable growth in Zimbabwe.

The limited studies available on agriculture's role in Zimbabwe's economy are centred on examining the impact of agriculture expenditure on economic growth. These include the works of Mapfumo (2012), Matandare (2018), and Saungweme and Matandare (2014). In differing with these studies, we employ agricultural production as a variable of interest in assessing the role of agriculture on the economic growth of Zimbabwe. In the existing literature there is also the work of Mapfumo (2013), providing an econometric analysis of the relationship between agricultural production and economic growth in Zimbabwe. In differing with this study we employ a different econometric methodology and examine both the short-run and long-run contribution of agricultural production to Zimbabwe's economic growth using a longer time frame with the most recent data available.

The rest of this article is organised as follows: a broader overview of Zimbabwe's agricultural sector, literature review, methodology and data, econometric results, conclusion and policy implications.

Overview of Zimbabwe's Agricultural Sector

After the country obtained its independence in 1980, various agricultural policies were implemented, including land reform programmes and support of local farmers with advice, inputs and funding to improve agricultural production. Zimbabwe inherited a heavily government-backed agricultural sector from the Smith Administration (Saungweme and Matandare 2014). Land reform programmes started in 1980 as an effort to achieve a more equitable distribution of land, although many have criticised the 2000 land reform programme as having failed to end hunger and having increased malnutrition. Gumede (2018) shows that before the land reform, the country was agriculturally almost self-sufficient, but land reform collapsed agricultural productivity to such an extent that the country ended up importing most products.

The land reform of Zimbabwe focused exclusively on taking successful commercial farms. As a result, agricultural productivity was affected. Zimbabwe's exports income was reduced, and food production was also disrupted as productivity plummeted. Contrary to this, Thomas (2003) argued that it is difficult to say the land reform programmes alleviated Zimbabwe's economic crisis because, as the country was pursuing its recovery by stimulating agricultural potential through land reforms, the approach exposed the country to international threats and sanctions. On the other hand, Gonese et al. (2002) also highlighted that the land reform programme was subsequently beset with major challenges arising from heightened demand for land at a time of its marked unavailability on the market and from grossly inadequate funding to enhance agricultural productivity. According to the International Trade Administration (2022), following the government's fast-track land reform programme which began in 2000, irrigation infrastructure deteriorated, and most of the new landowners depend on rain rather than irrigation for their crops. As the weather pattern changes and droughts become more frequent, the country has failed to produce enough grain to meet domestic demand.

The government also subsidised the agriculture sector to promote and empower both small- and large-scale farmers. The International Trade Administration (2022) states that during the 2020/2021 agricultural season, the government allowed the private sector to fund agricultural activities, which improved transparency in the sector. The government has taken steps to promote cultivation of sorghum and millet, which are more ecologically compatible with Zimbabwe's semi-arid areas. Irrigation systems have been installed and, recently, smart agriculture is being adopted to ensure green, inclusive and sustainable development. The Food and Agriculture Organization (2022) mentions that agriculture is the backbone of Zimbabwe's economy since the population remains largely rural and people derive their livelihood from agriculture and other related rural economic activities. Rates of poverty are higher in rural areas than in urban areas. Therefore, to ensure shared prosperity, there is a need to support agricultural production, be it on a subsistence or commercial level. FAO (2022) shows that agricultural activities in Zimbabwe provide employment and income to 60–70% of the population, supply 60% of the raw materials required by the industrial sector, and contribute 40% of total export earnings.

Zimbabwe is a landlocked country with a total land area of over 39 million hectares, with 33.3 million hectares used for agricultural purposes (FAO 2022). There are about 6 million hectares that have been reserved for national parks and wildlife, and urban settlements. The country comprises four physio-geographic regions, which are the Eastern Highlands, the Highveld, the Middle veld, and the Low veld. The World Bank (The World Bank Group 2022b) states that the population is over 15 million and this information shows that land and labour are in abundance, and these are key resources needed in farming. These resources are adequate to expand agricultural production and strengthen comparative advantages over other countries.

FAO (2022) shows that agriculture contributes approximately 17% to Zimbabwe's GDP. As the main source of livelihood for most of the population, the performance of the agriculture sector is paramount for rural livelihood resilience and poverty levels. There are, however, challenges facing smallholder farmers including low and erratic rainfall, low and declining soil fertility, low investment, shortages of farm power – labour and draft animals, poor physical and institutional infrastructure, poverty, and recurring food insecurity. According to the World Food Programme (World Food Programme 2022), Zimbabwe was added to the list of FAO-WFP Hunger Hotspots in May 2022 due to an erratic rainfall season and consequent drop in expected crop production (which declined by 43% as compared to the previous year; farmers' yields shrunk by half).

The Zimbabwe agricultural sector still has challenges of gender inequality in terms of access to resources such as land. However, although men are still dominating the agriculture sector, women are increasingly getting involved. Traditionally, families believed in having bigger family sizes to assist with farming, and the bigger the family size the more the output and income. In this setup men were responsible for farming and hunting while women were responsible for the house and taking care of children. This disadvantaged the women as land ownership is skewed to the men. The majority of these farmers were farming for subsistence and barter trade. However, the current agricultural sector is composed of large-scale commercial farming and small-scale farmers, with the latter occupying more land area but located in regions where land is relatively infertile with more unreliable rainfall and poor or no irrigation systems.

Agriculture in Zimbabwe involves crop production, animal production, forestry, and fishing. Most rural homes have a separate piece of land where they can farm on a small scale or large scale. Their farm products include maize, tobacco, groundnuts, cotton, sheep, goats, and cows. Their produce is used either for family consumption, domestic trade, or exporting. The main agricultural export is tobacco, which is exported to countries like the Democratic Republic of Congo, South Africa, Botswana, China, Zambia, the Netherlands, and the United Kingdom.

Livestock keeping has also contributed significantly to the economy of Zimbabwe, with cattle accounting for 35% to 38% of the GDP contributed by the agricultural sector (FAO 2022). Most families in the rural areas of Zimbabwe either keep donkeys, cattle, sheep, goats, or chickens. FAO (2022) estimated that up to 60% of rural households own cattle and 70–90% own goats, while over 80% own chickens. The importance of livestock in rural livelihoods and food security lies in the provision of meat, milk, eggs, hides and skins, draught power, and manure. Livestock in Zimbabwe also acts as a strategic household investment. Small ruminants (sheep and goats) and non-ruminants, particularly poultry, are an important safety net in the event of drought – they are easily disposable for cash when the need arises. Zimbabwe's smallholder system has the potential to grow and become the mainstream of the livestock sector's performance indicator.

Forests cover 40% of Zimbabwe's total area, accounting for 15,624,000 hectares (The World Bank Group 2022b). However, according to FAO (2022), Zimbabwe has had a steady deforestation rate in the last twenty years. Deforestation is a result of poor access to energy in rural areas and a production capacity not able to meet increasing energy demand in urban areas. The deforestation rate averages 327,000 hectares lost annually since 1990, or more than 6 million hectares of forests lost in the last 2 decades (FAO 2022).

Agriculture production has not been having good returns due to various factors leading to food shortages. World Food Programme (2022) classified Zimbabwe as a lower-middle income and food-deficit country which over the last decade has experienced several economic and environmental shocks that have contributed to high food insecurity and malnutrition. At least 49% of its population live in extreme poverty- many impacted by the effects of climate change, protracted economic instability and global stressors.

As a tropical country, Zimbabwe generally experiences a dry savannah climate with high temperatures in most parts of the year. Maiyaki (2010)

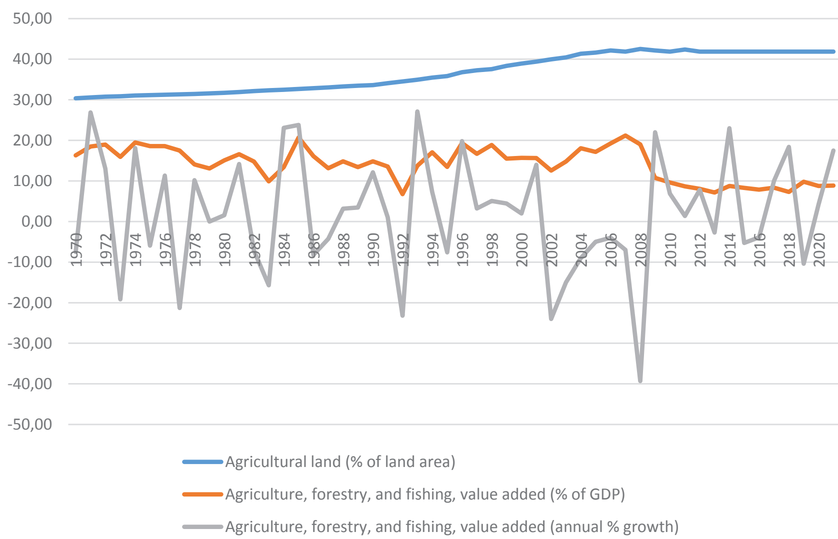

FIGURE 1 Agriculture Performance in Zimbabwe
(authors' elaboration of World Bank (2022b) data)

shows that Zimbabwe's climate is dependent on the rains brought by the Indian Ocean monsoons (seasonal winds). The Eastern part of the country has up to 1,000 mm of rainfall each year between the months of October and March. However, rain levels reduce to about half that amount in the dry southwest. Between March and October, there is very little, if any, rainfall and this is when the weather gets cold, with frosts common in the mountains and central plateau areas. Since the late 1970s, rainfall has been very irregular and there have been serious droughts and cyclones which have led to soil erosion in some areas and decreased agricultural production (Mapfumo 2013).

With its fertile land, Zimbabwe used not only to be self-sufficient but also to produce surplus agricultural goods for exporting to other neighbouring countries. However, the situation has changed in recent years to the extent that the country can no longer feed itself and depends on foreign aids and loans. Due to the previous economic and political issues and climate change, the Zimbabwean agricultural system has become weaker. As a landlocked country with over 63% of people living below the poverty line, the use of land for agricultural purposes has been increasing sharply since 2000 (World Food Programme 2022), as shown in figure 1.

The percentage of land used for agriculture has been increasing in past years although the country's agricultural productivity has been low due to

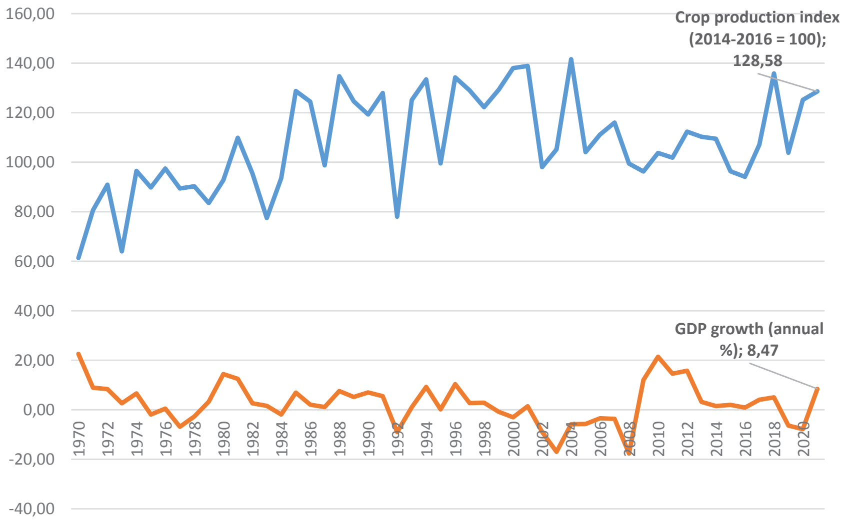

FIGURE 2 Crop Production Index versus GDP Growth (authors' elaboration of World Bank (2022b) data)

many factors such as widespread poverty, the outbreak of diseases such as HIV/AIDS, limited employment opportunities, liquidity challenges, recurring climate-induced shocks and economic instability. Despite increasing agriculture land use in Zimbabwe, agriculture contribution to its GDP has recorded a declining trend since 1985. Although agriculture, forestry and fishing value added as a percentage of GDP has recorded some recoveries over certain periods, this has not been the case after 2007 as agricultural contribution has been on the decline. Agriculture's annual percentage growth has been swinging between −39% and 27%.

Zimbabwe is characterised by lots of arable lands, with some parts of the country having good rainfall patterns, and there is lots of labour in the country. These are key factors of production that are required to boost agriculture. The World Food Programme (2022) shows that about 70% of the population is dependent on rain-fed farming, while most farmers are smallholders with low productivity. Due to several challenges, including economic crisis and lack of markets, agriculture in the country has been wobbly between 1970 and 2022, and eventually started decreasing between 2012 and 2020, as shown in figure 2. The decline in agricultural production could also be associated with global disasters such as climate change as famers are still adjusting to this and others are struggling with financing climate change activities.

Literature Review

SOLOW MODEL

Agriculture production affects economic growth through various channels. Various theoretical frameworks can be linked to the relationship between agriculture production and economic growth. For brevity purposes, we link this study to the Solow model. According to Hoeffler (2002), in the Solow model, growth in output depends on initial output per worker, y (0), the initial level of technology, A (0), the rate of technological progress, g, the savings rate, s, the growth rate of the workforce, n, the depreciation rate, δ, the share of capital in output, α, and the rate of convergence to the steady state, λ. Hoeffler (2002) further explained that the model predicts that a high savings rate will affect growth in output per worker positively whereas high labour force growth (corrected by the rate of technological progress and rate of depreciation) will have a negative effect on growth in output per worker. As given by Hoeffler (2002) the Solow basic model is stated as:

$$\begin{aligned}\ln y_t - \ln y_0 = {} & -1(1 - e^{-\lambda}) \ln y_0 + (1 - e^{-\lambda}) \ln A_0 \\ & + gt + (1 - e^{-\lambda}) \frac{\alpha}{1 - \alpha} \ln s \\ & - (1 - e^{-\lambda}) \frac{\alpha}{1 - \alpha} \ln(n + g + \sigma), \end{aligned} \tag{1}$$

where y_t denotes the logarithm of output per worker in period t.

The above Solow growth model relates to this study through two channels. As articulated by Safdar, Maqsood, and Ullah (2012), high agriculture production volatility means more income risk, which tends to raise precautionary savings, which in turn encourages investment in the agriculture sector and helps in boosting economic growth. As given by the Solow model, a high savings rate will affect growth in output per worker positively, which in turn increases productivity. In contrast, a high agriculture production volatility may also mean more investment risk in the agriculture sector, which tends to discourage investment in the agriculture sector and thereby slowing down economic growth.

In the Cobb-Douglas production function based on constant returns to scale as given by

$$Y = K^a L^{1-a}, \tag{2}$$

where Y is output level produced for a given employment levels of inputs capital (K) and labour (L). The relationship between inputs and outputs is positive. This relates to this study as labour force participation in the agriculture sector is also important in determining agriculture performance, thereby causing increases in agricultural production and thus the GDP of Zimbabwe.

THE EMPIRICAL LITERATURE ON AGRICULTURE AND ECONOMIC GROWTH

To date, there is well-documented research to probe the impact of agricultural production on growth for several developing countries. Many studies adopt the Solow-Swan neoclassical growth theory to analyse the impact of agriculture on growth. On the standard Solow-Swan growth equation, agriculture is added as an engine for growth, and this is used to measure the linkages between the rural and industrial sectors of the economy (Hwa 1983).

The Literature on Developed Countries

Most developed countries do not necessarily specialise in agricultural production because of limited agricultural resources and because their weather conditions are not conducive for farming and livestock rearing. Developed countries are capital abundant and produce capital-intensive goods. The Heckscher-Ohlin theory states that countries with lots of labour produce labour-intensive goods while capital-abundant countries produce capital-intensive goods (Markusen 2005). Although machinery is increasingly getting used in agriculture, lots of labour remains the main factor.

There is a handful of research focusing on the relationship between agriculture production and growth in developed economies and this includes the works of Katircioglu (2006), Yao (2000), and Xuezhen, Shilei, and Feng (2010). Katircioglu (2006) employed the Granger causality to show a bi-directional relationship between agriculture production and growth in North Cyprus. Yao (2000) shows that although agriculture's share in GDP declined sharply over time in China, it is still an important force for the growth of other sectors, resulting in an overall increase in China's economy. The decline in agriculture's share in GDP over time was as a result of China's government policies biased against agriculture to industrialise the economy. Nevertheless, Yao (2000) further ascertained that without agriculture providing enough food for the population, materials for industries, large capital transfers to state revenue and foreign exchange, the entire economy can suffer enormously. Xuezhen, Shilei, and Feng (2010) concur that although the share of agriculture in GDP has declined significantly over time in China, the contribution of agricultural growth has maintained an upward trend and it has made important market, foreign exchange, factor (finance and labour), and output contributions to non-agricultural growth and thus it remains an irreplaceable driving force for economic growth in China.

The Literature on Developing Countries

The effect of agriculture on economic growth in developing countries has yielded more debate. Most developing countries, particularly African nations, have a comparative advantage in producing labour-intensive agricultural goods. There is a bountiful amount of research focusing on establishing the impact of agriculture on economic growth in developing economies. These studies include the works of Ansari, Rashid, and Alam (2022), Agboola et al. (2022), Uddin, Rahman, and Majumder (2022), Oyinbo and Rekwot (2014), Jatuporn et al. (2011), Awokuse and Xie (2015), Odetola and Etumnu (2013), Izuchukwu (2011), Sertoglu, Ugural, and Bekun (2017), Awan and Aslam (2015), Raza, Ali, and Mehboob (2012), Awokuse (2009), Moussa (2018) and Uddin (2015). Whether a study was investigating the impact of agriculture on growth or causal direction between agriculture production and growth, the prime conclusion for all of them was that agriculture is of paramount importance regarding the economic growth of these developing countries. Jatuporn et al. (2011) show the existence of a long-term stable bi-directional relationship running from agriculture to economic growth and from economic growth to agriculture in Thailand. Moussa (2018) reveals that GDP per capita, agricultural value added, and the human development index have a long-run relationship in the case of Benin. Adding to that, an expansion of the agricultural sector will have a significant impact on the economy in the long run and ameliorate the living conditions of the population. Awan and Aslam (2015) concluded that the economic growth of Pakistan can be increased due to a positive trend in agriculture value added. A recent study by Ansari, Rashid, and Alam (2022) shows that while the production of wheat, rice, and tobacco has a positive impact on India's GDP development, the production of pulses and sugarcane has an inverse, but not insignificant, impact. Uddin, Rahman, and Majumder (2022) also reveal that agriculture has a positive impact on Bangladesh's GDP in the long run and short run.

The effect of agriculture production on the economic growth of Nigeria has also been widely researched. Literature based on Nigeria only includes the works of Agboola et al. (2022), Oyinbo and Rekwot (2014), Odetola and Etumnu (2013), Izuchukwu (2011), and Sertoglu, Ugural, and Bekun (2017). One thing that these studies are congruent about is that agriculture has a significant positive effect towards the Nigerian economic growth. The works of Agboola et al. (2022) concluded that the effect of forestry, crop production and fishery on Nigeria's economic growth is statistically significant and positive. However, Odetola and Etumnu (2013) show that although agriculture contributes to growth, growth itself does not increase agriculture, indicating no reverse causality. On the other hand, Izuchukwu (2011) took a different turn and reveals that there is a positive relationship between Gross Domestic Product (GDP), and the Government Expenditure on Agriculture and Foreign Direct Investment on Agriculture.

In assessing this relationship, various estimation techniques were employed. The ARDL helps in distinguishing between the short-run and long-run effects influencing a relationship and the Granger causality test has the ability to examine many lags, with higher-order lags discounted. The works of Oyinbo and Rekwot (2014), Jatuporn et al. (2011), Awokuse and Xie (2015), Odetola and Etumnu (2013), Awan and Aslam (2015), and Awokuse (2009) employed the ARDL cointegration technique and the Granger causality test to test for the directional effect. Sertoglu, Ugural, and Bekun (2017) and Moussa (2018) employed the Johansen test and the Vector Error Correction Model (VECM). On the other hand, Raza, Ali, and Mehboob (2012) employed the Ordinary Least Squares (OLS) method while Izuchukwu (2011) employed the SPSS technique.

The Literature on Zimbabwe's Case

Due to the insubstantial availability of studies focusing on the agriculture-growth nexus in Zimbabwe, five studies were reviewed. This section includes the works of Mapfumo (2012; 2013), Bautista and Thomas (1999), Saungweme and Matandare (2014), and Matandare (2018). The studies by Mapfumo (2013) and Matandare (2018) employed the Johansen test while Mapfumo (2012) and Saungweme and Matandare (2014) employed the OLS estimation technique. Bautista and Thomas (1999) employed the Social Accounting Matrix (SAM) in determining the impact of agricultural production on Zimbabwe's economic growth. Despite the different estimation techniques employed, all these studies come to the same conclusion that agriculture is vital for the economic growth of Zimbabwe.

Matandare (2018) shows that agriculture has a long-run impact on Zimbabwe's growth, while Mapfumo (2012) suggests that spending more on agricultural research and development can improve economic growth and ultimately reduce poverty.

Furthermore, empirical analysis by Mapfumo (2013) provides strong evidence indicating that agricultural production is important in improving the wellbeing of countries, especially in Zimbabwe. The results from Mapfumo (2013) suggest that the value of agricultural production of tobacco, maize and cotton positively affected economic growth in Zimbabwe from 1980 to 2010. Saungweme and Matandare (2014) indicate that increased agriculture expenditure before 2000 has boosted production in the sector and strengthened forward and backward economic linkages. However, the land reform programme of 2000 and subsequent reduction in sound government support to the sector contributed immensely to the economic crises in Zimbabwe.

Methodology and Data

MODEL SPECIFICATION

The model specified is an extension of the Solow model, by including the role of agricultural production, government expenditure and inflation in influencing growth. The model used to examine the impact of agricultural production on economic growth was therefore expressed as follows:

$$\begin{aligned}\mathrm{GDP}Grwth_t &= \beta_0 + \beta_1 Infl_t + \beta_2 Agric_t + \beta_3 \mathrm{GFCF}_t \\ &\quad + \beta_4 GvtExp_t + \beta_5 Pop_t + \varepsilon_t, \end{aligned} \tag{3}$$

where $\mathrm{GDP}Grwth_t$ is real gross domestic product growth at time t, $Infl_t$ is inflation rate at time t, proxied by GDP deflator, $Agric_t$ is agricultural production index, GFCF_t is gross fixed capital formation as a share of GDP at time t, $GvtExp_t$ is general government expenditure as a share of GDP at time t, Pop_t is the population at time t, β_0 is the intercept, $\beta_1, \beta_2, \ldots, \beta_5$ are the slope coefficients to be estimated, and ε_t is the white noise error term. The variables were included in the model based on theory. The Solow Growth Model shows that capital, as proxied by gross fixed capital formation and labour, as proxied by population plays a pivotal role in promoting growth. While the Solow Growth Model neglected the role of land and the environment in influencing growth, the model also considers that since Zimbabwe is an agro-based economy, agricultural production plays a pivotal role in promoting growth. In addition, inflation is one of the macroeconomic problems the economy is facing, with monetarist theory showing that money supply has influence on output in the short run and on inflation in the long run.

The Keynesian theory also shows that high government expenditure plays a pivotal role in stimulating aggregate demand and promoting growth, thus justifying the inclusion of inflation and government expenditure as variables in the model.

STATIONARITY TEST

The unit root test/stationarity test was done using the Augmented Dickey-Fuller (ADF) unit root test to determine the order of integration of the variables, and the ADF is specified as follows:

$$y_t = \mu + \beta_t + \gamma_0 y_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta y_{t-i} + \varepsilon_t, \tag{4}$$

where y_t is the variable under consideration, $\mu, \beta, \gamma_0, \gamma_i$ are parameters of the model, ε_t is the white noise error term, and y_{t-i} denotes lag differences of the variable under consideration with lag p. The ADF test is an extension of the Dickey-Fuller test, for it accommodates some form of serial correlation (Greene 2003). If γ_0 is statistically significant, then the series is stationary, otherwise, the series must be differenced d times to be stationary.

AUTOREGRESSIVE DISTRIBUTED LAG (ARDL) COINTEGRATION

In order to analyse the impact of agricultural production on economic growth, the study used the Autoregressive Distributed Lag (ARDL) model by Pesaran and Shin (1998) and Pesaran, Shin, and Smith (2001). The ARDL approach is preferred over other traditional cointegration models such as the Engle-Granger cointegration test and the Johansen and Juselius cointegration test, since these apply to series that are integrated of the same order I(d) only. The ARDL model can be applied to series that are integrated of order one I(1), order zero I(0), or mutually cointegrated. Thus, the ARDL model is appropriate regardless of the integration of the variables, whether they are stationary in levels I(0) or after first difference I(1) or both of mixed order of integration. The ARDL model also takes small sample size and simultaneity biases in the relationship between the variables in the model. The ARDL approach to cointegration was specified as follows:

$$\begin{aligned}\Delta\text{GDP}Grwth_t = \beta_0 &+ \sum_{i=0}^{p}\beta_1\Delta\text{GDP}Grwth_{t-1} + \sum_{i=0}^{q}\beta_2\Delta Infl_{t-1}\\ &+ \sum_{i=0}^{r}\beta_3\Delta Agric_{t-1} + \sum_{i=0}^{s}\beta_4\Delta\text{GFCF}_{t-1}\\ &+ \sum_{i=0}^{t}\beta_5\Delta GvtExp_{t-1} + \sum_{i=0}^{u}\beta_6\Delta Pop_{t-1}\\ &+ \alpha_1\text{GDP}Grwth_{t-1} + \alpha_2 Infl_{t-1} + \alpha_3 Agric_{t-1}\\ &+ \alpha_4\text{GFCF}_{t-1} + \alpha_5 GvtExp_{t-1} + \alpha_6 Pop_{t-1} + \varepsilon_t, \qquad (5)\end{aligned}$$

where β_0 is the intercept, $\beta_1, \beta_2, \ldots, \beta_6$ represent the short-run dynamic coefficients of the variables, while $\alpha_1, \alpha_2, \ldots, \alpha_6$ represent the long-run coefficients, and $p, q, r, s, t, u$are the lag length which is determined automatically using the Akaike Information Criterion (AIC). Several model diagnostic tests were done. The F-test was used to test the existence of a long-run relationship between the variables in the model. The null hypothesis that there is no cointegration was stated as follows:

$$\text{H}_0\colon \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = \alpha_6 = 0. \qquad (6)$$

The alternative hypothesis that there is cointegration between the series was specified as follows:

$$\text{H}_1\colon \alpha_1 \neq 0, \alpha_2 \neq 0, \alpha_3 \neq 0, \alpha_4 \neq 0, \alpha_5 \neq 0, \alpha_6 \neq 0. \qquad (7)$$

If the null hypothesis is rejected, then the variables are cointegrated and the error correction model (ECM) must be estimated. The error correction model is used to show the speed of adjustment towards the long-run equilibrium and was expressed as follows:

$$\begin{aligned}\Delta\text{GDP}Grwth_t = \beta_0 &+ \sum_{i=0}^{p}\beta_1\Delta\text{GDP}Grwth_{t-1} + \sum_{i=0}^{q}\beta_2\Delta Infl_{t-1}\\ &+ \sum_{i=0}^{r}\beta_3\Delta Agric_{t-1} + \sum_{i=0}^{s}\beta_4\Delta\text{GFCF}_{t-1}\\ &+ \sum_{i=0}^{t}\beta_5\Delta GvtExp_{t-1} + \sum_{i=0}^{u}\beta_6\Delta Pop_{t-1}\\ &+ \lambda\text{ECM}_{t-1} + \varepsilon_t, \qquad (8)\end{aligned}$$

where ECM_{t-1} is the error correction term, and λ is the parameter indicating speed of adjustment towards the long run equilibrium. The serial correlation test was done using the Breusch-Godfrey LM test while the Breusch-Godfrey-Pagan test was used to test for heteroscedasticity. The test for normality of residuals was done using the Jarque-Bera test while the Cumulative Sum of Squares (CUSUMSQ) was used to test for model parameter stability. The Ramsey Regression Specification Error Test (RESET) was used to test for model misspecification.

DATA SOURCES AND DESCRIPTIVE STATISTICS

Data Sources

The study used annual data for the period 1970 to 2019 from the World Development Indicators (WDI). The study used this particular period because of data availability on all the variables in the study, and the period is long enough to perform regression analysis. The variables are described in table 1.

In this study, GDP growth was used as a proxy for economic growth, GDP deflator was used as a proxy for inflation, and the agricultural production index was used as a proxy for agricultural production.

Descriptive Statistics

The summary statistics on the variables used in this study are shown in table 2. The summary shows that GDP growth, gross fixed capital formation as a share of GDP, and government expenditure as a share of GDP have been relatively stable over the study period compared to agricultural production, inflation and population as shown by low standard deviation. The maximum values of GDP growth, agricultural production, gross fixed capital formation as a share of GDP, inflation, and government expenditure as a share of GDP show that the Zimbabwean economy at some point recorded high growth, high agricultural production, high

TABLE 1 Description of the Variables and their Source

Variable	Explanation	Data Source
GDP*Grwth*	Real GDP Growth	WDI
Inf	GDP Deflator	WDI
Agric	Agricultural Production Index	WDI
GFCF	Gross Fixed Capital Formation as a share of GDP	WDI
GvtExp	Government Expenditure as a share of GDP	WDI
Pop	Population	WDI

TABLE 2 Descriptive Statistics

Item	*Agric*	GDP*Grwth*	GFCF	*Infl*	*Pop*	*GvtExp*
Mean	97.02	2.59	14.13	3.75	10399590	16.79
Median	94.93	2.24	14.77	2.63	11336229	17.91
Maximum	125.71	22.57	24.58	95.41	14645468	27.49
Minimum	55.45	−17.67	2.00	−27.05	5289303	2.05
Std. Dev.	17.73	8.14	5.65	15.91	2732645	5.11
Skewness	−0.24	−0.03	−0.43	3.67	−0.417235	−0.80
Kurtosis	2.31	3.49	2.63	23.46	1.951	4.10
Jarque-Bera	1.45	0.52	1.82	984.89	3.743209	7.81
Probability	0.48	0.77	0.40	0.00	0.153877	0.02
Observations	50	50	50	50	50	50

gross fixed capital formation as a share of GDP, high inflation, and high government expenditure as a share of GDP over the study period.

The minimum values of GDP growth, agricultural production, gross fixed capital formation as a share of GDP, inflation, and government expenditure as a share of GDP show that the Zimbabwean economy at some point recorded poor growth, poor agricultural production, poor gross fixed capital formation as a share of GDP, deflation, and low government expenditure as a share of GDP over the study period. The variables used in the study are negatively skewed and normality distributed as shown by kurtosis, the Jarque-Bera statistic and its probability value, except for inflation, which are positively skewed and not normally distributed. However, the skewness and normality of the variables does not affect the results of the study.

Econometric Results

The ADF unit root test was done, and the results show that all the variables were non-stationary in levels except agricultural production index, inflation, and GDP growth. Thus, gross fixed capital formation as a share of GDP, government expenditure as a share of GDP, and population were found to be non-stationary in levels while inflation, GDP growth, and agricultural production index were found to be stationary in levels I(0). The ADF unit root test results are shown in table 3.

The series that were non-stationary in levels were differenced once and became stationary. Thus, gross fixed capital formation as a share of GDP,

TABLE 3 Augmented Dickey-Fuller Unit Root Test Results

	Variable	ADF test statistic	Critical value at			Decision
			1%	5%	10%	
(a)	GDP*Grwth*	−4.64613	−3.57131	−2.92245	−2.59922	Stationary I(0)
	Infl	−6.18359	−3.57131	−2.92245	−2.59922	Stationary I(0)
	Agric	−4.74446	−3.57131	−2.92245	−2.59922	Stationary I(0)
	GFCF	−2.57766	−3.57131	−2.92245	−2.59922	Non–stationary
	GvtExp	−2.89507	−3.57131	−2.92245	−2.59922	Non–stationary
	Pop	−1.63015	−3.58474	−2.92814	−2.60222	Non–stationary
(b)	D(GFCF)	−8.68921	−3.57445	−2.92378	−2.59992	Stationary I(1)
	D(*GvtExp*)	−7.40431	−3.57445	−2.92378	−2.59992	Stationary I(1)
	D(*Pop*)	−3.82828	−4.21913	−3.53308	−3.19831	Stationary I(1)

NOTES Row headings are as follows: (a) ADF Unit root test results in levels, (b) ADF Unit root test results after first difference.

TABLE 4 ARDL Bounds Test Results Using Narayan (2005) Critical Values

Significance	Lower Bound	Upper Bound
10%	2.435	3.6
5%	2.900	4.218
1%	3.955	5.583

NOTES *F*-statistic = 7.6116 (significant at 10% level). Critical values are obtained from Narayan (2005), Table Case III: Unrestricted intercept and no trend.

government expenditure as a share of GDP, and population were found to be integrated of order one I(1), and the results are shown in table 3.

Since some of the variables were I(0) and others were I(1), there is the possibility of a long-run relationship between the variables, and the ARDL bounds test was used to examine if the variables are cointegrated. The optimum lag length was determined using the Akaike Information Criterion (AIC) and the model with lags (3, 3, 1, 4,0, 3) was chosen. The AIC is superior to the other criteria in the case of a small sample (60 observations and below), in a manner that may minimise the chance of under estimation while maximising the chance of recovering the true lag length (Liew 2004). The ARDL bounds test results are shown in table 4.

The sample size used in this study is small, less than 100 observations, hence Narayan (2005) critical values were used. If the *F*-statistic is below the lower critical bound values, then the null hypothesis that there is no cointegration between the variables fails to be rejected. However, if the F-statistic is above the upper bound critical values, the null hypothesis is rejected and we conclude that there is cointegration among the variables. If the F-statistic falls between the lower bound critical values and the upper bound critical values, then the test is inconclusive. The ARDL bounds test shows that there is cointegration among the variables since the F-statistic (7.6116) lies above the upper bound critical value (5.583) at a 1% significance level. Since the F-statistic is statistically significant at a 1% level, there is a long-run equilibrium relationship among the variables and the short-run model, and the long-run model must be estimated.

The study results show that the variables are cointegrated and there is a long-run equilibrium relationship between the variables. The short-run and long-run model were therefore estimated.

SHORT-RUN AND ERROR CORRECTION MODEL

In table 5, the error correction model and the short-run coefficients of the ARDL model are presented. The estimated ARDL model passed all the model diagnostic tests. There was no serial correlation, residuals were normality distributed, there was no heteroscedasticity, and the model was correctly specified. The model parameters were also found to be stable. See table 6 and figure 3 for the model diagnostic test results.

The short-run results show that coefficients of GDP growth with lags one and two are positive and statistically significant at 1% and 10%, respectively. This implies that economic growth depends on the first period and the second period lagged values in the short run. Thus, an increase in the first period lagged and the second period lagged GDP growth by 1% result in an increase in economic growth by 0.58% and 0.23%, respectively, ceteris paribus. Past economic growth has an influence on future economic growth rates, and to ensure sustained economic growth, initially experiencing high economic growth is a prerequisite. The coefficient of inflation with lag zero is positive and statistically significant at a 1% level while the coefficient of inflation with lag two is negative and statistically significant at a 1% level. This shows that the current period inflation has a positive impact on economic growth, but the second period lagged inflation has a negative impact on economic growth. Thus, an increase in current inflation by 1% results in an increase in economic growth by 0.23% while an increase in the second period lagged inflation by 1% results in a decrease in economic growth by 0.24% in the short run, holding other factors constant. This shows that current inflation has a positive effect on economic

TABLE 5 Short-Run Results and the Error Correction Model

Variable	Coefficient	Std. Error	t-Statistic	Probability
D(GDP*Grwth*(−1))	0.57952***	0.19326	2.99870	0.0059
D(GDP*Grwth*(−2))	0.23474*	0.13175	1.78161	0.0865
D(*Inf*)	0.23445***	0.04884	4.80016	0.0001
D(*Inf*(−1))	−0.07594	0.06179	−1.22905	0.2301
D(*Inf*(−2))	−0.24091***	0.06040	−3.98828	0.0005
D(*Agric*)	0.19277***	0.05463	3.52849	0.0016
D(GFCF)	0.83624***	0.27974	2.98929	0.0060
D(GFCF(−1))	0.51454*	0.25405	2.02535	0.0532
D(GFCF(−2))	−0.31838	0.23999	−1.32658	0.1962
D(GFCF(−3))	−0.72994	0.24401	−2.99140	0.0060
D(*GvtExp*)	0.38788*	0.21286	1.82225	0.0799
D(*Pop*)	−0.00020	0.00023	−0.88621	0.3836
D(*Pop*(−1))	0.00102	0.00069	1.47249	0.1529
D(*Pop*(−2))	−0.00040	0.00024	−1.64793	0.1114
CointEq(−1)	−1.41584***	0.23204	−6.10180	0.0000

NOTES *, ** and *** means statistically significant at 10%, 5% and 1% level, respectively.

TABLE 6 Model Diagnostic Test Results

Test	Test statistic	Calc. value	P-value	Conclusion
Autocorrelation	F-statistic	0.20547	0.8157	There is no autocorrelation
	Obs*R-squared	0.77437	0.6790	
Normality Test	Jarque-Bera	0.27507	0.8715	Residuals normally distrib.
Ramsey RESET	F-statistic	0.00031	0.9861	Model correctly specified
	t-statistic	0.01762	0.9861	
Heteroscedasticity	F-statistic	0.67467	0.8099	No heteroscedasticity
	Obs*R-squared	15.1901	0.7104	

growth, while past inflation is harmful to economic growth. Thus, while positive inflation levels are desirable to attract investment and promote growth, high levels of inflation are harmful to future economic growth.

The coefficient of the agricultural production index was found to be positive and statistically significant at a 1% level, implying that agricultural production has a positive effect on economic growth in the short run. Thus, an increase in agricultural production by 1 unit results in an increase in economic growth by 0.19% in the short run, ceteris paribus.

This is because agricultural production plays a pivotal role in the early stages of economic development, supplying raw material to the industrial sector and promoting economic growth. The results are consistent with the results of Mapfumo (2012; 2013), Bautista and Thomas (1999), Saungweme and Matandare (2014), and Matandare (2018), among other studies. The coefficient of gross fixed capital formation as a share of GDP was found to be positive and statistically significant at a 1% level, implying that a 1% increase in the share of gross fixed capital formation in GDP results in a 0.84% increase in economic growth, holding other factors constant. The coefficient of one period lagged share of gross fixed capital formation in GDP was found to be positive and statistically significant at 10%. This implies that a 1% increase in one period lagged share of gross fixed capital formation in GDP results in an increase in economic growth by 0.51%, ceteris paribus. The coefficient of share of government expenditure in GDP was found to be positive and statistically significant at a 10% level, implying that a 1% increase in the share of government expenditure in GDP results in an increase in economic growth by 0.39% in the short run, ceteris paribus.

The error correction coefficient of –1.42 measures the speed of adjustment towards the long-run equilibrium and is statistically significant at a 1% level. The results show that the system corrects the previous period disequilibrium at a speed of 142%, and this shows that the system is overcorrecting the disequilibrium to reach the long-run equilibrium steady-state position. Thus, the long-run equilibrium is reached in less than one year and error correction terms between –1 and –2 imply that the equilibrium is achieved in a decreasing form (Narayan and Symth 2004).

LONG-RUN RESULTS

The results from the long-run model show that inflation, the share of gross fixed capital formation in GDP, population, and share of government expenditure in GDP have a positive impact on economic growth. The long-run results are shown in table 7.

The coefficient of inflation was found to be positive and statistically significant at a 1% level, implying that a 1% increase in inflation results in an increase in economic growth by 0.43% in the long run, ceteris paribus. The coefficient of share of gross fixed capital formation in GDP was found to be positive and statistically significant at a 1% level, implying that a 1% increase in the share of gross fixed capital formation in GDP results in an increase in economic growth by 1.13%, holding other things constant. The coefficient of the population was also found to be positive and statistically

TABLE 7 Long-Run Results

Variable	Coefficient	Std. Error	*t*-Statistic	Probability
Inf	0.43242***	0.10967	3.94306	0.0005
Agric	0.04364	0.05936	0.73506	0.4689
GFCF	1.13238***	0.23099	4.90233	0.0000
GvtExp	0.27396*	0.14226	1.92572	0.0651
Pop	0.00000***	0.00000	3.32687	0.0026
C	-41.01054***	8.87248	−4.62222	0.0001

NOTES *, ** and *** means statistically significant at 10%, 5% and 1% level, respectively.

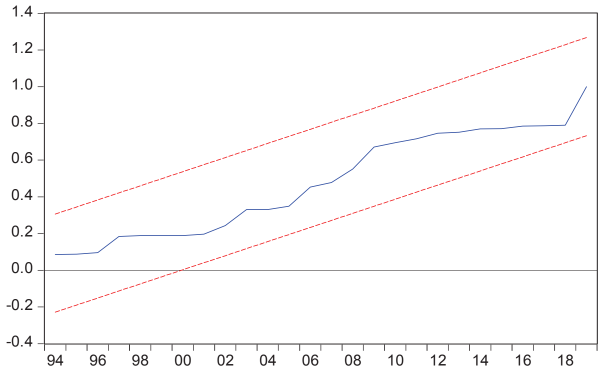

FIGURE 3 Cumulative Sum of Squared Residuals (blue – CUSUMQ, red – 5% significance)

significant at a 1% level, but the impact on economic growth was found to be small. However, the coefficient of agricultural production was found to be insignificant, implying that in the long run, economic growth is insignificantly influenced by agricultural production. This is because in the long run, when the Zimbabwean economy becomes more developed, it will not be very dependent on agriculture but will be relying much more on the industrial modern sector. In line with the theory, agricultural production plays a pivotal role in the short run, at the early stages of economic development, supplying raw material to the industrial sector, but when the economy is developed, it plays a minimal role.

Conclusion and Policy Implications

This study examined the impact of agricultural production on economic growth in Zimbabwe using data for the period 1970–2019. The ARDL bounds test was used to examine whether there is a long-run equilibrium relationship between the variables in the model. The study found that agricultural production has a positive impact on economic growth in the short run, and no impact on economic growth was found in the long run. Thus, the agricultural sector plays an important role in the early stages of economic development, and when the economy is developed, it contributes insignificantly to economic growth. The study found that inflation, the share of government expenditure in GDP, and the share of gross fixed capital formation in GDP have a positive effect on economic growth in both the short run and long run. However, the population was found to have no impact on the economy in the short run but had a positive effect in the long run.

The results imply that to promote economic growth, there is a need to ensure a sustainable inflation level, increasing government expenditure and gross fixed capital formation. The Zimbabwean economy has poor infrastructure and to promote growth, there is a need to promote gross fixed capital formation through spending on land improvements; plant, machinery, and equipment purchases; and construction of infrastructures such as roads, dams, railways, private residential dwellings, and commercial and industrial buildings, as this would attract investment in the country. The Zimbabwean economy is agro-based, and there is a need to boost agricultural production through various measures such as plugging the loopholes in the existing land legislation so that surplus land may be distributed among the small and marginal farmers, and providing adequate credit facilities at reasonable cheap rates to farmers. Fiscal incentives are required for organisations that are supporting farmers with funding, advice, inputs and other raw materials. In its budget, the Zimbabwe government should increase investment in the development of infrastructure and rehabilitation of old infrastructure used by farmers. Additionally, the government should not underestimate the value of women in agriculture. Policies are needed to empower women in agriculture and increase women's access to land and other relevant resources. With the growing effects of climate change on weather patterns, there is also a need to practice smart agriculture, especially in areas receiving poor rainfall, for the security of the crops. There is a need to identify climate smart crops and increase research on plant breeding, which considers the unique soil types of Zimbabwe, as a major requirement.

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Capital Structure, Firm Performance and Risk Exposure: New Evidence from OECD Countries

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Optimal capital structure is a key tool to take advantage of the trade-off between firm performance and risk. Based on this, we examine how optimal capital structure influences corporate performance and risk exposure. We use a strong-balanced panel of 3,344 firm-year observations from 10 different OECD countries for 2006–2016. Results reveal that firms having short-term debt normally experience high accounting-based performance while lowering market-based performance, firms using long-term and total debt are largely exposed to decreased accounting and market-based performance. The higher the long-term and total debt, the greater the chances that firms become vulnerable to insolvency risk. Findings are robust across alternative indicators of capital structure, firm performance and risk, alternative model development and the two-step system GMM estimator to control endogeneity issues. This research will be of importance to firm managers and policymakers in designing an appropriate capital structure for maximizing firm performance while minimizing debt-taking risks.

Key Words: capital structure, performance, risk, Organization for Economic Cooperation and Development (OECD)
JEL Classification: G2, G3, M4

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Introduction

Capital structure is a vital corporate financing decision for making a trade-off between financial benefits, non-financial benefits and debt-taking costs (Nazir, Azam, and Khalid 2021). Financial benefits refer to the increases in a firm's profitability, while the non-financial benefits indicate tax-shield advantage as well as investors' favourable perceptions and attitudes regarding the firm's investment competitiveness (Papangkorn et al. 2021). The financial and non-financial benefits are, together, termed as the indicators of firm performance (Alkurdi 2022; Li, Niskanen, and Niskanen 2018). The debt-taking cost, in contrast, is the severity of experiencing operational losses by the firm and the probability that it is exposed to bankruptcy risk (Nazir, Azam, and Khalid 2021). The operational losses and bankruptcy are combinedly coined as firm risk indicators (Jiang et al. 2020). An optimal capital structure is a point where firms can take advantage of this trade-off by maximizing firm performance and minimizing the associated firm risks (Abdullah and Tursoy 2021). Thus, a natural research question arises: How much debt and equity firms should maintain in order to reach an optimal capital structure to make this trade-off? Until now, this research question has not widely been investigated in the corporate finance literature.

Motivated by this important research gap, the significance of optimal capital structure in attracting risk-averse investors, and the differential effects that the optimal capital structure has on firm performance and firm risk exposure, we have performed this study. Our study investigates the influences of optimal capital structure on the corporate performance and risk exposure of the listed firms of ten different OECD countries for the time span of 2006 to 2016. Moreover, the foundations of this study rely on three established corporate finance theories, namely agency cost theory, pecking order theory, and trade-off theory. As per the agency cost theory, an optimal capital structure puts pressure on the firm managers to act in the best interests of the stakeholders, thereby minimizing the firm's agency costs (Danso et al. 2020). The pecking order theory states that firms should finance their projects using their internally retained earnings at first as it is free from information asymmetry (Abdullah and Tursoy 2021). In the case where additional funding is needed, firms should turn to debt financing. Lastly, firms should issue equity to address the remaining capital requirements. The trade-off theory argues that the optimal capital structure helps in balancing the tax-shield advantage of debt and the severe cost of debt (Khoa and Thai 2021). Under this theory, firms prefer to use more debt, owing to the advantage of the tax shield.

The contributions of the study are fourfold. First, earlier studies have concentrated on exploring the effects of optimal capital structure on a firm's performance using only accounting-based performance metrics such as return on assets and return on equity. For instance, Abdullah and Tursoy (2021) confirm a positive association between capital structure and firm performance, as measured by the return on asset and return on equity. In contrast, Nazir, Azam, and Khalid (2021) report an inverse relationship between capital structure and the firm's profitability performance, as measured by return on asset and net profit margin. Li, Niskanen, and Niskanen (2018) portray similar evidence but moderate the capital structure-firm performance relationship using the financial crisis. Our study differs from its predecessors by examining the capital structure-firm performance relationship using both accounting and market-based firm performance metrics. Specifically, rather than focusing only on return on asset and return equity, this study employs Tobin's Q as a measure of market performance in studying capital structure-firm performance association. These two measures, together, provide a comprehensive proxy of firm performance that measures not only financial profitability but also investors' attitudes and perceptions regarding the firm's future growth and investment opportunities.

Our study further employs a comprehensive firm risk perspective in relation to capital structure. Specifically, both operational and bankruptcy risk proxies are used for examining the role of optimal capital structure in minimizing firms' financial risks, which have not hitherto been examined in prior corporate finance studies (Abdullah and Tursoy 2021). Second, while preceding studies use data up to 2013, this study extends the dataset to 2016 to include a more comprehensive extent of the aforementioned relationship. Third, unlike previous studies on capital structure, we investigate sixty-four diverse industries of ten developed countries that belong to the Organization for Economic Cooperation and Development (OECD). This broad examination allows us to form a comprehensive understanding of the financial structure, corporate performance and risk exposure of these developed countries. Fourth and finally, this study applies an econometric methodology of panel regression estimation using alternative measures of optimal capital structure. This methodology addresses the probable endogeneity issue of debt financing, firm performance and firm risk relationship using firm-fixed effects and the two-step system GMM approach. Overall, our study is unique and distinct from the previous studies in this corporate finance literature with regard to both theoretical and empirical contributions.

This study reveals that short-term debt positively influences firms' accounting-based performance measures (Return-on-asset and Return-on-equity) while long-term and total debt negatively impact both the firm's accounting and market-based performance measures (Return-on-asset, Return-on-equity and Tobin's Q). Moreover, the long-term and total debt significantly contribute to enhancing the firm's insolvency risks, while short-term debt increases operational risks. This study's findings reinforce that short-term debt contributes to the financial profitability performance of the listed OECD firms by reducing information asymmetry and agency conflicts between the firm's shareholders and managers. Since the listed firms of these countries have low growth, they should avoid long-term and total debt financing owing to the chances of being bankrupt. The current research, however, reveals that though short-term debt financing is enhancing financial profitability, it further brings associated operational risks for the firms. The outcomes of the research may be useful for the firm managers, owners and policymakers in developing an optimal capital structure conducive to enhancing the firm's financial performance and reducing risk exposure.

The remainder of the paper is organized as follows. Section 2 represents prior studies and related hypotheses. Section 3 shows the study methodology and preliminary analysis. The panel regression model for the capital structure and the related model results are presented in section 4. Sections 5 and 6 end with the additional tests and conclusions of the study.

Extant Literature and Hypotheses Formulation

CAPITAL STRUCTURE AND FIRM PERFORMANCE

Capital structure is defined as the mixture of a variety of funding sources to maintain optimal funds for financing a firm's projects (Farhan et al. 2020). It is the combination of debt and equity that the firm adopts for financial operations and business growth (Dao and Ngoc Ta 2020; Ojonta, Obodoechi, and Ugwu 2021). The capital structure aims to maximize the firm's financial value and minimize the overall cost of capital (Chadha and Sharma 2015). In this regard, financial value refers to the firm's performance on profitability metrics as well as investment competitiveness within the industry (Abdullah and Tursoy 2021). Profitability metrics are the yielding of financial gains as measured by financial statement-based data such as return on asset, return on equity, basic earning power and so on (Sheikh and Wang 2013). On the other hand, investment competitiveness is the firm's ability to shape investors' attitudes and perceptions in a positive way and generate their interest to invest in the firm's business (Jamadar et al. 2022). Earlier literature resorts to several theories in explaining the capital structure-firm performance relationship. MM theory, agency cost theory, pecking order theory, trade-off theory and signalling theory are some of the prominent ones (Dao and Ngoc Ta 2020). Following previous literature, this study picks up the agency cost theory, pecking order theory and trade-off theory to develop the grounds of the study.

As per the agency cost theory, an optimal capital structure plays a significant role in decreasing agency costs between shareholders (agents) and managers (principals) of a firm (Li, Niskanen, and Niskanen 2018). More precisely, financing through debt puts pressure on managers to focus more on stakeholders' benefits that contribute to the reduction of the firm's agency cost (Yazdanfar and Öhman 2015). Thus, firms choose to employ debt financing in order to mitigate agency conflict between managers and shareholders, which brings enhanced firm value (Sheikh and Wang 2013). The theory further suggests that debt financing through issuing short-term debt instead of long-term debt plays a more dominant role in resolving agency conflicts and enhancing firm value (Myers 1977). Prior empirical studies support this theoretical assertion and confirm that short-term debt financing is positively associated with the firm's value as measured by the profitability metrics (Ayaz, Zabri, and Ahmad 2021; Singh and Bagga 2019). Therefore, this study hypothesizes that:

H1a *Short-term debt financing is positively associated with the profitability of the firms of OECD countries as measured by financial statement-based data.*

The agency cost theory further draws on the stock-based firm performance metric 'Tobin's Q' in analysing the impacts of capital structure on firm value. The previous empirical stance highlights this theoretical assertion and shows that short-term debt financing is negatively related to the market-based firm performance indicator 'Tobin's Q' (Mehmood, Hunjra, and Chani 2019; Olajide, Funmi, and Olayemi 2017). Thus, this study hypothesizes that:

H1b *Short-term debt financing is negatively associated with the with the profitability of the firms of OECD countries as measured by market-based data.*

Regarding long-term debt financing, it is found that long-term debt involves high fixed costs and relatively larger out-of-pocket costs (Dalbor and Upneja 2002). Moreover, long-term debt involves more risks as it facilitates transferring wealth to stockholders (Moradi and Paulet 2019). Owing to these shortcomings, owners and managers of low-growth firms do not prefer to finance their profitable projects by employing external risky capital sources (Yazdanfar and Öhman 2015). This notion is consistent with the theory of pecking order which states that firms should first go for internal financing in raising capital rather than external capital financing (Myers and Majluf 1984). If internal financing falls short of investment, firms should look for low-risk debt financing (Li, Niskanen, and Niskanen 2018). Thus, the theory suggests that having more long-term debt obstructs firm performance, whether measured by accounting-based or stock-based metrics. The theory further sheds light on total debt financing sources by depicting an inverse relationship with firm performance. Based on this theoretical stance, we can state that:

H2 *Long-term debt financing is negatively related to the firm performance of OECD countries as measured by accounting or marker-based data.*

H3 *Total debt financing is negatively related to the firm performance of OECD countries as measured by accounting or marker-based data.*

CAPITAL STRUCTURE AND FIRM RISK

Firm risk plays a crucial role in the decision of capital structure (Dao and Ngoc Ta 2020). Those firms who are likely to have higher business risk exposure have less ability to undertake financial risks, thereby preferring less debt financing (Kim and Sorensen 1986). A number of corporate finance theories assert the presence of an inverse relationship between capital structure and firm risk. For instance, the trade-off theory suggests that high-risk firms should not be highly levered due to the probability of being in default (Khoa and Thai 2021). The pecking order theory (POT) provides a more precise stance on the capital structure-firm risk relationship. As per the theory, higher volatility in earnings increases the chance that a firm will become bankrupt (Li, Niskanen, and Niskanen 2018). This bankruptcy presents the firm with low creditworthiness likely to obtain debt (Alipour, Mohammadi, and Derakhshan 2015). Thus, bankruptcy or insolvency risk increases with the undertaking of more debt financing. However, more profitable firms have lower exposure to insolvency risk which has led them to employ higher debt financing (Li, Niskanen, and Niskanen 2018). Moreover, high debt financing brings more opportunities for firms to exploit interest tax breaks (Viviani 2008). Based on this argument, we posit that:

H4 *Firms' capital structure and insolvency risk in OECD countries are positively associated with each other.*

The pecking order theory suggests a positive relationship between capital structure and operating risk (Viviani 2008). According to the theory, the lower variability in net profit enables firms to rely more on retained earnings and less on external financing (Alipour, Mohammadi, and Derakhshan 2015). As a result, firms need not boost their projects through debt financing. The reduction of debt financing brings a decreased level of operating risks for firms. Earlier studies also reflect this theoretical stance through empirical estimations and confirm the negative association between debt financing and a firm's operational risk (Abor and Biekpe 2009; Sheikh and Wang 2011). Based on these theoretical foundations and empirical evidence, this study posits that:

H5 *Firms' capital structure and operational risk in OECD countries are positively associated with each other.*

Methodology

STUDY SAMPLE AND DATA

The purpose of the study is to explore how capital structure impacts firm performance and risk-taking behaviour. The study sample consists of listed firms from 10 different European countries, namely Denmark, Spain, Finland, France, Germany, Italy, Norway, Portugal, Sweden and the United Kingdom. Precisely, a total of 295 firms and 3344 firm-year observations have been considered. These countries are included in the sample in consideration of their homogeneous and comparable economic development. All of the countries are members of the OECD who have experienced similar inflation rates, interest rates, per capita GDP and discretionary income. However, these countries differ in terms of the development of financial and banking systems, the legal regulatory environment and corporate operations. This sample selection pattern coincides with the study of Vallelado and Saona (2011). Our study sample is dominated by firms from the United Kingdom, with the highest number of firms at 85 (table 1). France and Germany subsequently occupy the second and third positions.

Earlier 'capital structure' research covered periods up to 2013 (Chadha and Sharma 2015; Li, Niskanen, and Niskanen 2018). This study aims to fill the prior research gap and contribute to the existing capital structure literature by considering subsequent periods. Therefore, the study

TABLE 1 Sample Countries, Number of Firms and Firm-Year Observations

Country	(1)	(2)	(3)	Country	(1)	(2)	(3)
Denmark	17	187	11.00	Italy	21	242	11.52
Spain	27	308	11.40	Norway	22	253	11.50
Finland	23	264	11.47	Portugal	14	165	11.78
France	33	374	11.33	Sweden	25	286	11.44
Germany	28	319	11.39	United Kingdom	85	946	11.13

NOTES Column headings are as follows: (1) number of firms, (2) observations, (3) observations per firm. Total 295 firms (3344 observations). Based on data sourced from Thomson Reuters Eikon (https://eikon.thomsonreuters.com).

starts with 2006 and ends with the year 2016. However, the study does not consider recent time frames (2017–2021), owing to the unavailability of relevant firm-level data. The total data set comprises 295 firms from 64 diverse industries. However, industry-wise detailed information has not been considered in this research. The capital structure perspective is extensively examined using only firm-level data from 10 OECD countries. Overall, the study sample consists of debt, financial and risk-related information sourced from Thomson Reuters Eikon.

CAPITAL STRUCTURE MEASURES

Our study considers short-term debt, long-term debt, total debt and leverage as the measures of a firm's capital structure. The short-term debt ratio (STD_{it}) is calculated as the short-term debt over total assets (Hussain et al. 2020). Firms with higher STD_{it} are likely to undergo continuous renegotiations that may result in credit supply shock and financial difficulties (Vallelado and Saona 2011). The long-term debt ratio (LTD_{it}) is measured as the long-term debt to total assets (Hussain et al. 2020). Bigger firms in developed countries prefer to have more LTD_{it} since they have an effective legal system in place (Yazdanfar and Öhman 2015). The total debt ratio (TTD_{it}) is calculated as the total debt over the total asset (Moradi and Paulet 2019). TTD_{it} is the sum of long-term debt and interest-bearing short-term debt. In calculating total debt, non-interest-bearing liabilities (deferred tax, accounts payable and accrued liabilities) are not given any consideration.

This study further controls for firm size, growth, intangibility and ownership structure. Firm size (SIZE_{it}) is calculated by taking a logarithmic transformation of total firm assets, Growth (GROWTH_{it}) denotes the %

change in a firm's sales in a particular year (Abdullah and Tursoy 2021); intangibility (INTANG_{it}) is the ratio of total intangible assets to total equity (Margaritis and Psillaki 2010) and ownership concentration (OWN_{it}) is the average of shares owned by the major stakeholders of the firms (Hussain et al. 2020).

Firm Performance Measures

Our study classifies firm performance measures into two broad categories, namely accounting-based performance measures and market/stock-based performance measures. Accounting-based performance measures refer to the firm's financial profitability in a particular year, while market-based performance measures indicate shareholders' expectations regarding the firm's current and future financial operations (Papangkorn et al. 2021). Our study concentrates on two accounting-based performance measures following Khan, Al-Jabri, and Saif (2021), namely Return on asset (ROA_{it}), Return on equity (ROE_{it}) and one market-based measure including Tobin's Q (TQ_{it}). The ROA_{it} is calculated by taking the ratio of the firm's net profit after tax to the total reported assets. The ROA_{it} exhibits the firm's efficiency in generating a net profit by utilizing the firm's total assets. The ROE_{it} is the ratio of the firm's net profit after tax to the total shareholder's equity. It measures how much returns or earnings a firm is offering to its shareholders. Tobin's Q (TQ_{it}), the market-based measure, is obtained by summarizing the market value of stocks and the book value of debt divided by the book value of total assets. It represents the firm's position in terms of its replacement cost. TQ_{it} measures the firm's stance on competitive advantage and dynamism. A TQ_{it} value >1 suggests that firms have higher investment opportunities, growth potential and systematic resource management capabilities.

Firm Risk Measures

Our study considers the operational and insolvency risk exposure of the listed European firms. Asset return volatility (ARV_{it}) is used as the proxy measure of operational risk, following Psillaki and Daskalakis (2009) and Alipour, Mohammadi, and Derakhshan (2015). This is calculated as the standard deviation of return on assets over a 5-year overlapping window. This study further uses an additional measure of operational risk, namely stock return volatility (SRV_{it}), following Sun and Chang (2011). This is measured as the standard deviation of the daily stock return multiplied by the square root of the trading day number in a financial year. The higher the asset return or stock return volatility, the greater the severity of the firm's operational risk exposure. The insolvency risk is proxied by *Z*-score ($Zscore_{it}$), following Kumar, Colombage, and Rao (2017). It is the ratio of the summarization of ROA and capital-to-asset divided by the asset return volatility. $Zscore_{it}$ is an inverse measure of the firm's risk. This study takes the natural logarithmic transformation of the *Z*-score in order to remove the influences of skewness and outliers. This transformation coincides with the study of Laeven and Levine (2009).

ANALYSIS

Descriptive Statistics

The descriptive information of the variables relating to firm performance, risk, capital structure and firm-level control variables is shown in table 2. Accounting performance is measured by the ROA_{it} and ROE_{it}. These variables deviate considerably across 3344 firm-year observations from –0.395 to 1.343. The market-based performance variable, TQ_{it}, ranges from 0.68 to 7.45. Both accounting and market-based measures of firm performance have significant variations within the data range, as indicated by their descriptive statistics in table 2. The operational and insolvency risk measures have considerable differences in their mean values, with $Zscore_{it}$ having a mean value >3. The implication is that firms within the industries are less likely to have insolvency risk exposures. Regarding the capital structure variables, the LTD_{it} ratio is found to be higher than STD_{it} and TTD_{it} across the sampled firms. Furthermore, the firms in the study have an average SIZE_{it} of 23. The year-to-year percentage change in firm sales (GROWTH_{it}) is around 3.7%. With an INTANG_{it} ratio of 32.1%, the sampled firms are offering a good source of collateral to the lenders. Lastly, the percentage of shares held by individual shareholders is ±30%, indicating high ownership concentrations (OWN_{it}) for the sample firms.

Correlation Matrix

This section covers the Pearson Correlation analysis of the study variables (table 3). The matrix finds that both accounting and market-based 'Firm Performance' measures (ROA_{it}, ROE_{it}, TQ_{it}) at a 10% level are inversely associated with the firm's capital structure as measured by STD_{it} and LTD_{it}. This inverse relationship is also observed when the capital structure of the sampled firms is measured by TTD_{it}. This offers a source of robustness regarding the capital structure-firm performance relationship. In contrast, capital structure is found to have a positive relationship with all the risk

TABLE 2 Descriptive Statistics

Acronyms	Study variables	(1)	(2)	(3)	(4)	(5)
ROA	Return on Asset	3201	0.049	0.078	−0.395	0.334
ROE	Return on Equity	3155	0.156	0.228	−0.659	1.343
TQ	Tobin's Q	3085	1.669	1.064	0.676	7.450
ARV	Asset Return Volatility	3344	0.078	0.005	0.070	0.086
SRV	Stock Return Volatility	3344	0.227	0.009	0.213	0.243
Zscore	*Z*-Score	2639	3.051	2.141	0.552	14.662
STD	Short-term debt	1373	2.906	0.133	2.373	3.200
LTD	Long-term debt	3057	3.046	0.109	1.883	3.268
TTD	Total debt	3199	0.260	0.167	0.000	1.571
SIZE	Firm size	3201	23.008	1.835	10.314	28.421
GROWTH	Sales growth	2822	0.037	0.182	−0.996	1.000
INTANG	Intangibility	3077	0.321	0.530	−0.576	3.366
OWN	Ownership concentration	3195	0.317	0.231	0.000	1.000

NOTES Column headings are as follows: (1) observations, (2) mean, (3) standard deviation, (4) minimum, (5) maximum. This table represents the descriptive statistics for the balanced panel of 3344 firm-year observations for the period 2006–2016.

measures but is statistically significant only to $Zscore_{it}$ at the 10% level. The matrix, however, finds no high correlations among the study variables. This is further verified by the Variance Inflation Factor (VIF) test (table 4). The mean value of the test is 2.455, which is far below the threshold level of the test, indicating no multicollinearity issue in the study.

Results and Discussion

To empirically examine the assertion that capital structure has an impact on firm performance and risk-taking behaviour, we employ the following baseline panel-regression models:

$$Performance_{it} = \alpha + \beta\ Capital\ structure_{it} + \gamma X_{it} + \varepsilon_{it} \quad (1)$$

$$Risk_{it} = \alpha + \beta\ Capital\ structure_{it} + \gamma X_{it} + \varepsilon_{it}, \quad (2)$$

where i and t denote the firm and year, respectively. $Performance_{it}$ refers to the firm's financial performance as measured by accounting and market-based indicators (ROA_{it}, ROE_{it}, TQ_{it}), $Capital\ structure_{it}$ indicates four proxies used to measure firm capital structure (STD_{it}, LTD_{it}, TTD_{it}), $Risk_{it}$ denotes the firm risk exposure as measured by operational (ARV_{it} and

TABLE 3 Study Correlation Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1)ROA	1.000													
(2)ROE	0.737*	1.000												
	(0.000)													
(3)TQ	0.527*	0.429*	1.000											
	(0.000)	(0.000)												
(4)ARV	−0.064*	−0.058*	−0.147*	1.000										
	(0.000)	(0.001)	(0.000)											
(5)SRV	−0.092*	−0.078*	−0.134*	0.900*	1.000									
	(0.000)	(0.000)	(0.000)	(0.000)										
(6)Zscore	0.598*	0.300*	0.806*	−0.098*	−0.100*	1.000								
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)									
(7)STD	−0.077*	−0.046	−0.132*	0.019	0.032	−0.228*	1.000							
	(0.004)	(0.093)	(0.000)	(0.479)	(0.236)	(0.000)								
(8)LTD	−0.181*	−0.073*	−0.384*	0.007	0.015	−0.545*	0.413*	1.000						
	(0.000)	(0.000)	(0.000)	(0.717)	(0.416)	(0.000)	(0.000)							
(9)TTD	−0.108*	0.054*	−0.147*	0.035	0.041	−0.489*	0.091*	0.368*	1.000					
	(0.000)	(0.002)	(0.000)	(0.045)	(0.019)	(0.000)	(0.001)	(0.000)						
(10)SIZE	−0.054*	−0.036	−0.352*	−0.034	−0.010	−0.368*	0.546*	0.722*	−0.001	0.159*	1.000			
	(0.002)	(0.043)	(0.000)	(0.056)	(0.554)	(0.000)	(0.000)	(0.000)	(0.960)	(0.000)				
(11)INTANG	−0.013	0.113*	−0.005	−0.023	−0.020	−0.024	0.052	0.024	0.022	0.314*	0.024	1.000		
	(0.467)	(0.000)	(0.799)	(0.207)	(0.272)	(0.220)	(0.056)	(0.200)	(0.231)	(0.000)	(0.188)			
(12)GROWTH	0.151*	0.117*	0.164*	−0.041	−0.063*	0.122*	−0.044	−0.083*	−0.048	−0.015	−0.129*	0.006	1.000	
	(0.000)	(0.000)	(0.000)	(0.031)	(0.001)	(0.000)	(0.126)	(0.000)	(0.011)	(0.444)	(0.000)	(0.760)		
(13)OWN	−0.007	−0.015	0.017	0.037	0.021	−0.032	−0.085*	−0.170*	0.143*	−0.002	−0.184*	0.001	0.027	1.000
	(0.683)	(0.394)	(0.353)	(0.035)	(0.230)	(0.104)	(0.002)	(0.000)	(0.000)	(0.908)	(0.000)	(0.967)	(0.151)	

NOTES This table shows the Pearson correlation matrix for the firm performance, risk, capital structure and firm-level control variables. *P*-values are shown in parentheses; * indicates significance at the 10% level.

TABLE 4 Collinearity Statistics

Acronyms	Study Variables	VIF	Tolerance
STD	Short-term debt	1.594	0.627
LTD	Long-term debt	4.532	0.221
TTD	Total debt	3.032	0.330
SIZE	Size	4.665	0.214
GROWTH	Intangibility	1.203	0.832
INTANG	Sales Growth	1.023	0.978
OWN	Ownership concentration	1.140	0.877

SRV_{it}) and insolvency risks ($Zscore_{it}$), X is the firm-level control variable and ε_{it} is the stochastic error term. These panel regression models differ from the earlier studies on capital structure in that the models incorporate market-based firm performance measures and firm-level risk measures to offer a comprehensive stance on the optimal capital structure-firm performance-firm risk relationship. Table 5 provides a summary of the novel features of our study models in comparison to the previous studies of optimal capital structure. We start by estimating these baseline regression models using the FE-Generalized Least Square (GLS) model. Then, we examine the robustness of the estimations using the Two-step system GMM.

CAPITAL STRUCTURE AND FIRM PERFORMANCE: FIXED EFFECT ESTIMATION

To estimate Equation (1), this study first runs fixed and random effect regression models separately for the strongly balanced panel of 3344 firm-year observations for the time 2006–2016. The study then conducts the Hausman Specification test to determine the validity of the fixed and random effect estimations. With the χ^2 value of 30.04 (P = 0.000), the Hausman test rejects the null hypothesis, thus preferring the fixed-effect model for investigating the capital structure-firm performance relationship.

Panel A of table 6 reports the fixed effect regression results for examining the role of capital structure in financial performance. Contrary to the expectation and studies of Salim and Yadav (2012) and Sheikh and Wang (2013), STD_{it} is significantly associated with a firm's accounting-based performance measures (ROA_{it} and ROE_{it}). One possible explanation for such positive impacts is that profitable firms could find it easier to finance their required working capital through short-term debt. However, LTD_{it} is in-

TABLE 5 Summary of Comparison between the Current Study and the Related Earlier Studies on Optimal Capital Structure

Previous literature			Study Gaps				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sheikh and Wang (2013)	Firm performance and capital structure (1,440 firm-year obs.)	Agency issue causes high-debt policy that results in lower performance.	Yes	No	No	No	Pakistan
Yazdanfar and Öhman (2015)	Firm performance and debt financing (63,588 firm-year obs.)	Firm performance and debt financing are inversely related.	Yes	No	No	No	Sweden
Abdullah and Tursoy (2021)	Firm performance and capital structure (2,448 firm-year obs.)	Highly levered firms enjoy high firm performance.	Yes	No	No	No	Germany
Nazir, Azam, and Khalid (2021)	Firm performance and capital structure (340 firm-year obs.)	Agency issue causes high-debt policy that results in lower performance.	Yes	No	No	No	Pakistan
Ngatno, Apriatni, and Youlianto (2021)	Firm performance, capital structure and corporate governance (1,253 firm-year obs.)	Capital structure and firm performance are positively related to each other.	Yes	No	No	No	Indonesia
Our Study	Firm performance, firm risk and capital structure (3,344 firm-year obs.)		Yes	Yes	Yes	Yes	OECD countries

NOTES Column headings are as follows: (1) authors, (2) study focus, (3) main findings, (4) accounting-based performance measure, (5) market-based performance measure, (6) operational risk, (7) insolvency risk, (8) region/country.

versely associated with accounting-based performance measures, which are in line with Yazdanfar and Öhman (2015). Overall, TTD_{it} is significantly negative to both accounting and market-based performance measures. Regarding the firm-level control variables, only GROWTH_{it} is statistically positive to all the performance indicators, suggesting that the year-to-year percent increases in firm sales leads to the sharp increase of firms' ROA_{it}, ROE_{it} and TQ_{it}, significantly. The F-statistics of all the models

TABLE 6 Capital Structure-Firm Performance-Firm Risk Association (Fixed Effect Estimation)

Acronyms	Variables	Panel A: Firm Performance			Panel B: Firm Risk		
		(1)	(2)	(3)	(4)	(5)	(6)
STD	Short-term debt	0.033**	0.095*	−0.242	0.004	0.005	−0.237
		(0.033)	(0.09)	(0.178)	(0.112)	(0.231)	(0.399)
LTD	Long-term debt	−0.082**	−0.254**	−0.634	0.002	0.005	−2.068***
		(0.017)	(0.039)	(0.114)	(0.625)	(0.589)	(0.000)
TTD	Total debt	−0.157***	−0.262***	−1.123***	0.002	0.001	−5.644***
		(0.000)	(0.007)	(0.001)	(0.658)	(0.94)	(0.000)
SIZE	Firm size	−0.003	−0.027	−0.018	−0.006***	−0.008***	−0.128
		(0.57)	(0.107)	(0.744)	(0.000)	(0.000)	(0.115)
GROWTH	Growth	0.064***	0.182***	0.169**	−0.001	−0.004**	0.59***
		(0.000)	(0.000)	(0.025)	(0.219)	(0.015)	(0.000)
INTANG	Intangibility	−0.02***	0.002	−0.156**	0.001	0.001	−0.535***
		(0.001)	(0.926)	(0.029)	(0.36)	(0.495)	(0.000)
OWN	Ownership conc.	−0.026**	−0.112**	−0.724***	0.005***	0.008**	−1.03***
		(0.039)	(0.015)	(0.000)	(0.009)	(0.027)	(0.000)
	Constant	0.318***	1.347***	5.136***	0.198***	0.378***	14.745***
		(0.008)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)
	R-squared	0.200	0.256	0.168	0.220	0.187	0.341
	F-Statistics	28.78***	11.72***	8.32***	14.27	8.87	54.94
		(0.000)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)
	Observations	1105	1105	1095	1105	1105	1,021
	Groups	174	174	173	174	174	163

NOTES Column headings are as follows: (1) return on asset, (2) return on equity, (3) Tobin's Q, (4) asset return volatility, (5) stock return volatility, (6) Zscore. This table represents the fixed effect estimations for Panel A (Firm performance) and Panel B (Firm risk). Return on asset and Return on Equity represents the accounting-based performance measures, whereas Tobin's Q represents the market-based performance measure. Asset return volatility and Stock return volatility denote the operational risk measures, whereas the Zscore indicates the insolvency risk measure for the firms. *P*-values are shown in parentheses; *, **, and *** indicate significance at the 10%, 5% and 1% levels, respectively.

in Panel A are statistically significant at the 1% level, implying the validity of the regression estimation of the capital structure-firm performance relationship.

CAPITAL STRUCTURE AND FIRM RISK: FIXED EFFECT ESTIMATION

This section examines the impact of capital structure on the firm's risk-taking behaviour using Equation (2). Similar to the capital structure-firm performance relationship, this section, at first, runs the fixed and random effect model individually. With the χ^2 value of 102.312 ($P = 0.000$), the Hausman Specification test rejects the null hypothesis (H0) that the 'Random effect model is preferred for the study' and selects the fixed-effect model for examining the aforementioned relationship.

The estimation results of Equation (2) are reported in Panel B of table 6. The panel shows that the coefficients of STD_{it} are statistically positive but insignificant in all the risk models (Models 1–3). The results indicate that short-term debt financing has an impact on a firm's risk-taking behaviour but the magnitude of effects is not that considerable. When LTD_{it} and TTD_{it} are used as the proxy measures of capital structure, it leads to significant coefficients only for $Zscore_{it}$. More precisely, LTD_{it} and TTD_{it} are negatively associated with $Zscore_{it}$. Since $Zscore_{it}$ is an inverse measure of insolvency risk, its negative relationship with LTD_{it} and TTD_{it} implies the role of capital structure in increasing firms' insolvency risk exposure. Among all the firm-level control variables, only OWN_{it} is significantly negative to all the risk proxies, indicating that concentrated ownership increases the firm's operational and insolvency risk-taking tendencies. The F-test coefficients are statistically significant at a 1% level across all the risk models (Models 1–3), which confirms the validity of the panel regression estimation of the capital structure-firm risk relationship.

Additional Tests

The previous section shows the regression estimations for capital structure-firm performance-firm risk relationship using fixed-effect models for 1105 firm-year observations. This section presents the robustness of the earlier results related to capital structure, firm performance and firm risk. In addition to that, the moderating effect of firm risk is shown in the capital structure-firm performance.

CAPITAL STRUCTURE-FIRM PERFORMANCE: TWO-STEP SYSTEM GMM ESTIMATION

Capital structure and firm performance may be influenced by each other simultaneously. For instance, a high-performing firm may prefer to finance its assets through debt. In contrast, a mixture of debt and equity may determine the firm's financial profitability. To address this potential endogeneity issue regarding capital structure and performance relationship, this study employs the two-step system GMM approach, originally proposed by Blundell and Bond (1998), where appropriate instrumental variables are employed. The estimation outputs regarding the capital structure-firm performance relationship are presented in Panel A of table 7. As expected, all the performance measures are positively correlated with the prior values at the 1% level, indicating similarities between earlier and current firm performance. The table further reports the results of AR (1) and AR (2) of the first-order and second-order serial correlation test and Hansen J test of over-identification restriction. AR (1) and AR (2) are the autoregressive tools used to correct serial autocorrelation problems (Arellano and Bond 1991). The P-value of AR (2) and Hansen J test are statistically insignificant, thus failing to reject null hypotheses that the relationship does not have any second-order serial correlation and that the study instruments are valid. The study findings are consistent with the prior results reported in Panel A of table 6. Once again, the study confirms that long-term debt and total debt reduce firms' accounting and market-based financial performances. In contrast, short-term debt decreases a firm's market-based financial performance while enhancing the accounting-based performance measures.

CAPITAL STRUCTURE-FIRM RISK: TWO-STEP SYSTEM GMM ESTIMATION

Similar to the capital structure-firm performance relationship, this section offers robust evidence regarding capital structure and firm risk association using the two-step system GMM approach. The findings of the aforementioned relationship are presented in Panel B of table 7. Here, all the lag values of the risk proxies are statistically related to their current period values at the 1% level. The findings of AR (1), AR (2) and the Hansen J test are used to examine the robustness of the study relationship. The P-values of AR (2) and Hansen J test are statistically insignificant only to the $Zscore_{it}$ risk measure, thus failing to reject the null hypothesis that no second-order serial correlation and the study instruments are valid. Once again, the capital structure of a firm increases its insolvency risk-taking behaviour. However, despite the study finding that capital structure significantly impacts firms' operational risk-taking, no evidence is found regarding its robustness.

Conclusion and Policy Implications

This study is a new addition to the corporate finance literature which comprehensively investigates capital structure-firm performance-risk association using the listed firms of 10 different OECD countries. The

TABLE 7 Capital Structure-Firm Performance-Firm Risk Association (Two-Step System GMM)

Item	Panel A: Firm Performance			Panel B: Firm Risk		
	(1)	(2)	(3)	(4)	(5)	(6)
Return on asset$_{n-1}$	0.301*** (0.000)					
Return on equity$_{n-1}$		0.063*** (.000)				
Tobin's Q$_{n-1}$			0.244*** (0.000)			
Asset return volatility$_{n-1}$				0.611*** (0.000)		
Stock return volatility$_{n-1}$					0.456*** (0.000)	
Zscore$_{n-1}$						0.57*** (0.000)
STD	0.021 (0.15)	0.132** (0.012)	−0.061 (0.854)	0.004*** (0.001)	0.005** (0.019)	0.179 (0.797)
LTD	−0.036 (0.259)	−0.306*** (0.003)	−1.65* (0.079)	0.000 (0.981)	0.001 (0.847)	−5.759** (0.042)
TTD	−0.057** (0.037)	−0.222** (0.03)	−0.226 (0.655)	0.001 (0.45)	0.003 (0.393)	−6.111*** (0.000)
SIZE	0.005** (0.04)	0.004 (0.572)	0.046 (0.436)	0.000 (0.113)	0.000 (0.412)	0.199 (0.261)
GROWTH	0.054*** (0.00)	0.145*** (0.000)	0.276*** (0.000)	−0.001*** (0.002)	−0.003*** (0.000)	0.923*** (0.000)
INTANG	0.004 (0.497)	0.042* (0.085)	0.174 (0.168)	−0.001*** (0.001)	−0.001*** (0.004)	−0.171 (0.335)
OWN	−0.004 (0.663)	−0.022 (0.495)	−0.441 (0.104)	0.000 (0.919)	0.000 (0.921)	−1.906*** (0.002)
Constant	0.203** (0.011)	0.784*** (0.007)	8.271*** (0.000)	0.025*** (0.000)	0.118*** (0.000)	28.256*** (0.000)

Continued on the next page

panel regression estimation findings offer some novel findings. Among the capital structure measures, only short-term debt financing is positively significant to the firm's accounting-based performance measures, and negatively, insignificant to the market-based performance measure. These findings are in line with the implications of the agency cost theory and lend support to H1a and H1b. Regarding the long-term and total debt financing, the estimation results exhibit statistically inverse relationships with the firm's accounting and market-based performance measures, thereby supporting H2 and H3. These negative findings fur-

TABLE 7 *Continued from the previous page*

Item	Panel A: Firm Performance			Panel B: Firm Risk		
	(1)	(2)	(3)	(4)	(5)	(6)
Number of observations	1104	1103	1085	1105	1105	1004
Number of instruments	17	18	19	18	18	18
Number of groups	174	174	172	174	174	162
Wald Test	2949.08 (0.000)	588.34 (0.000)	1742.57 (0.000)	8.718 (0.000)	8.612 (0.000)	564.18 (0.000)
Arellano-Bond AR (1) (z, *p*-value)	−4.04 ($p = 0.000$)	−2.53 ($p = 0.011$)	−2.60 ($p = 0.009$)	−9.17 ($p = 0.000$)	−9.09 ($p = 0.000$)	1.67 ($p = 0.095$)
Arellano-Bond AR (2) (z, *p*-value)	−1.82 ($p = 0.069$)	−2.14 ($p = 0.072$)	−0.32 ($p = 0.747$)	−9.39 ($p = 0.000$)	−9.25 ($p = 0.000$)	−0.80 ($p = 0.421$)
Sargan test (Chi-square, *p*-value)	4.04 ($p = 0.775$)	27.22 ($p = 0.001$)	266.39 ($p = 0.000$)	897.04 ($p = 0.000$)	999.56 ($p = 0.000$)	68.12 ($p = 0.000$)
Hansen test (Chi-square, *p*-value)	3.69 ($p = 0.815$)	11.45 ($p = 0.177$)	44.22 ($p = 0.320$)	125.81 ($p = 0.000$)	127.95 ($p = 0.000$)	17.45 ($p = 0.261$)

NOTES Column headings are as follows: (1) return on asset, (2) return on equity, (3) Tobin's Q, (4) asset return volatility, (5) stock return volatility, (6) Zscore. This table shows the Two-step System GMM estimation results for capital structure, firm performance and firm risk relationship. Here, a one-year lag value is taken for the performance and risk measures. The Return on asset and Return on equity are the accounting-based performance measures and Tobin's Q is the market-based performance measure. The asset return volatility and stock return volatility are the operational risk measures and Zscore is the insolvency risk measure. The estimated coefficients and *p*-values are the two-way system GMM; AR(1) and AR(2) are the two test statistics that represent the first-order and second-order serial correlations, respectively. The Sargan test statistics test whether the model is overidentified, and the Hansen test statistics test the null hypothesis that all the instruments taken are valid for the study. *P*-values are in parentheses; *, **, and *** indicate significance at the 10%, 5% and 1% levels, respectively.

ther confirm the notion of the theory of pecking order that firms should avoid external long-term financing owing to its associated financial distress. The capital structure-firm risk relationship is exhibited as positively associated with the firm's operational risks while, negatively, significant to the insolvency risk, thereby proving H4 and H5.

The study findings offer a variety of implications for firm managers and owners, as well as policymakers of the OECD countries. The positive relationship between short-term debt and accounting-based firm performance implies that firms should prefer to use short-term debt to overcome the problems associated with information asymmetry (Öhman and Yazdanfar 2017). This will enable firms to reduce agency problems and the cost of financing (Abor and Biekpe 2009). The listed firms of the OECD countries, on average, have growth potential of less than 5%, as evidenced by the findings. Such low growth potential is one explanation of the inverse relationship that long-term and total debt has with the firm's performance (Abor and Biekpe 2009). Thus, firms should not go for seeking long-term debt in financing their projects. This implication is more pronounced for the capital structure-firm risk relationship as the higher the long-term and total debt, the greater the likelihood that firms become insolvent and bankrupt. Further, firms should try to reduce variability in their net profit-making in order to accumulate retained earnings for project financing. Such accumulated retained earnings will enable firms to lower their asset return volatility and stock return volatility, thereby decreasing the frequency and extremeness of the firm's operational risk losses.

This study is subject to some limitations. Firstly, the database used in the study covers the time period from 2006 to 2016. The incorporation of the recent database would help in better estimation of the study topic. Second, the capital structure-firm performance-firm risk relationship is estimated using the listed firms of the sixty-four diverse industries of OECD countries. The industry-wide separate estimation would give more in-depth results regarding the aforementioned relationship. Third, the study considers a total of 10 countries of OECD economies. Estimation using an individual country's firms would provide more country-specific insights regarding capital structure formation, financial performance and risk-taking behaviour. Moreover, each country has distinct laws, regulations and policy frameworks that may affect capital structure decisions. Thus, extant research should be conducted considering this limitation, to conduct more cross-country analysis. The data set includes a time frame from 2006 to 2016 which offers more room to conduct future studies on the pre-crisis, crisis and post-crisis periods (Danso et al. 2020). Another possible research area is to include some moderating variables such as firm size, firm age, financial flexibility, growth opportunities and gender diversity in the capital structure-firm performance relationship (Abdullah and Tursoy 2021; Moradi and Paulet 2019). The consideration of two more risk measures, namely liquidity and credit risk, would offer more robustness to the capital structure-firm risk relationship for the listed OECD firms (Li, Niskanen, and Niskanen 2018).

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Fossil Energy Consumption, Carbon Dioxide Emissions and Adult Mortality Rate in Nigeria

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The health implications of fossil energy consumption and carbon dioxide (CO_2) emissions remain a global concern. This study examines the effect of fossil energy consumption and CO_2 emissions on adult mortality rate in Nigeria. The study relies on the Health Production Function and utilises the Autoregressive Distributed Lag technique to analyse time series data from 1980 to 2019. The results of the estimated model show that fossil energy consumption reduces adult mortality rates in the short run, while CO_2 emissions increase adult mortality rates both in the short and long run. In addition, government health expenditure follows an inverted U-shape relationship in explaining adult mortality while foreign direct investment has a U-shape relationship with adult mortality in Nigeria. Trade openness and monetary policy are insignificant in the short and long run. It is recommended that the government should substitute clean energy for fossil fuel energy to improve the quality of life, strengthen CO_2 emissions tax and ensure health funds are used for the improvement of healthcare service delivery in Nigeria.

Key Words: adult mortality rate, CO_2 emissions, fossil energy consumption, Nigeria
JEL *Classification:* I15, I18, I12

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Introduction

Globally, the health sector has been recognised as an important force in any nation's growth and development process (Benjamin and Foye 2022).

This is because healthy living is a prerequisite for economic growth and development, and the quality of the healthcare system is linked directly to the people's quality of life. A healthy workforce enhances productivity, and the health of young adults is as vital as that of adults since they develop and become a more productive workforce in the future (Shobande 2020). Despite the general knowledge about the importance of healthy living, health issues remain a major challenge in Nigeria.

Nigerian health indicators are among the worst in Africa. Many people lose their livelihoods or die from different health conditions. At the same time, some suffer from disease burdens, including malaria, lower respiratory infection, neonatal disorders, diarrheal diseases, HIV/AIDS, ischemic heart disease, stroke, congenital defects, tuberculosis, and meningitis (Centers for Disease Control and Prevention N.d.; Oladosu, Chanimbe, and Anaduaka 2022). Malaria and other disease burdens, especially lower respiratory infection, the third major cause of death in developing countries (Akinyemi and Morakinyo 2018), significantly impact Nigerians as these affect their daily lives by increasing the cost of living and reducing productivity and income.

Efforts have been put in place by the government and international organisations, including the World Health Organisation (WHO), Centers for Disease Control, United States Agency for International Development (USAID), and United Nations Children's Fund (UNICEF) to address the diverse health challenges in Nigeria, some of which are related to fossil fuel use and CO_2 emissions. In 2019, the Nigerian government designs a National short-lived climate pollutants action plan highlighting 22 mitigation measures to reduce black carbon and methane emissions and co-emitted long-lived greenhouse gases, including CO_2 and other air pollutants from the transport, residential, industry, waste management, and agriculture sectors, among others. The policy aims to eliminate gas flaring by 100 percent and reduce emissions from oil production and processing, transportation, and distribution by 50 percent (International Energy Agency 2022).

The government is also committed to reducing greenhouse gas emissions through signing the Paris Agreement in September 2016. As noted in the current policy in the Nationally Determined Contribution, the government's vision is to transition from fossil fuels to clean energy and eliminate or reduce gas flaring and methane emissions. Moreover, the energy policy of the country aims to reduce the country's dependence on fossil fuels and use clean energy for rural electrification (Federal Ministry of

Environment 2021). Furthermore, USAID is collaborating with the Nigerian government to increase the health budget and strengthen the Nigerian primary health system to deal with different health challenges, including those resulting from CO_2 emissions and fossil fuels. In addition, the international body provides health inputs such as insecticide-treated bed nets and other kits to reduce the malaria burden, strongly linked to climate and environmental conditions (United States Agency for International Development N.d.). Moreover, WHO equips health centres with different facilities and trains healthcare professionals on disease prevention strategies to reduce disease-related deaths, including deaths resulting from the illnesses associated with carbon emissions and fossil fuels in Nigeria (World Health Organization N.d.).

Despite the efforts of the government and international organisations in addressing health challenges, little to no improvement has been recorded, as Nigeria remains one of the top disease burden countries worldwide (Pona et al. 2021). Climatic change and environmental conditions resulting from fossil energy consumption are common causes of health issues and high mortality rates in Nigeria (Effiong et al. 2022). Studies have linked the malaria burden to climate and environmental conditions, including stagnated water bodies, bad sewage disposal, and land pollution that favours mosquito breeding (Effiong et al. 2022; Ugwu and Zewotir 2020). Also, carbon dioxide (CO_2) emissions and other airborne particles from fossil energy consumption are negatively connected with public health, increasing respiratory and cardiovascular diseases and mortality rates (Shah et al. 2022; Urhie et al. 2020).

Fossil energy consumption is a force that drives economic growth, especially in resource-rich nations like Nigeria (Foye and Benjamin 2021a; Urhie et al. 2020). Fossil energy increases economic prosperity by creating jobs and value through the extraction, transformation, and distribution of energy products and services. There are two crucial channels through which energy contributes to the economic growth of any nation. These are the direct and indirect channels (World Economic Forum 2012). For the indirect channel, energy, most notably fossil energy, serves as input for the sectors of the economy. The manufacturing industry, for instance, uses fossil energy to produce plastic and petrochemical products, among others. Also, the agricultural sector relies on fossil energy for crop management and indirectly for fertilizer, pesticides, and machinery production (Woods et al. 2010; Center for International Environmental Law 2022). Moreover, energy is used to power the transportation, manufacturing, construction, and service sectors. Consequently, boosting economic growth and development, especially in developing countries, will spur energy consumption in various sectors of the economy (Foye and Benjamin 2021a; Urhie et al. 2020).

Meanwhile, an increase in fossil energy consumption not only boosts growth and development but also affects public health. Though fossil fuel consumption's primary effect differs from its secondary effect, both forms affect health outcomes (Foye 2022). Specifically, fossil energy consumption generates carbon emissions, which contribute significantly to outdoor or ambient air pollution, primarily when fossil fuel is used for industrial and automobile operations. These emissions advance into the atmosphere and become well mixed such that about the same amount is in the atmosphere everywhere (Foye 2022). While there are other greenhouse gas emissions such as nitrogen oxide, sulphur dioxide, methane and polyaromatic hydrocarbons, CO_2 emissions are the most dominant, causing global warming and deterioration of human health, especially in urban areas (Chen and Guo 2019; Foye 2018; World Health Organization 2021; Environmental Protection Agency N.d.). Carbon emissions pollute the air and increase atmospheric temperature levels (global warming/climate change) resulting in scarcity of water, rise in sea level, flooding, drought, and alternation in the patterns of infectious and vector-borne diseases. Air pollution also contributes to respiratory tract infections and poses a significant danger to human health. The result is high infant, under-5, and adult mortality and low life expectancy (Foye and Benjamin 2021b; Perera 2017; Weil 2014).

A critical review of the existing studies shows that limited or no existing studies examine the effect of fossil energy consumption and CO_2 emissions on adult mortality rate in Nigeria. In view of this, there is a need to investigate the effect of fossil energy consumption and CO_2 emissions on adult mortality rate in Nigeria. A precise knowledge of the relationship will enable the government to formulate appropriate policies to improve health quality and boost economic performance. Though the literature on the impact of fossil energy consumption and CO_2 emissions on health outcome indicators is replete, most of the studies focus on cross-country analysis which does not control for country-specific peculiarities; more so, their findings are contradictory (Adeleye, Azam, and Bekun 2023; Oyelade et al. 2020; Shobande 2020; Xing et al. 2019; Arawomo, Oyebamiji, and Adegboye 2018). The limited country-specific studies (Oyedele 2022; Urhie et al. 2020; Nkalu and Edeme 2019; Afolayan and Aderemi 2019) use either life expectancy, infant or under-5 mortality rates as health outcome indicators.

In addition, recent studies claim that government health expenditure (Oladosu, Chanimbe, and Anaduaka 2022; Onofrei et al. 2021), income (Adeleye et al. 2023; Oladosu, Chanimbe, and Anaduaka 2022), foreign direct investment (Immurana et al. 2023; Shah et al. 2022), trade openness (Byaro, Nkonoki, and Mayaya 2021), and monetary policy (Peter and Adediyan 2020) affect mortality rates. However, no available studies analyse their effects on adult mortality in Nigeria within a single model. This study, therefore, contributes to the growing literature by addressing these two gaps in Nigeria from 1980 to 2019 using the Autoregressive Distributed Lag (ARDL) technique. The outcome of this study is of immense benefit to the Sustainable Development Goals (SDGs), WHO, the government, and other relevant organisations that focus on promoting healthy living and well-being. Also, the study provides important information that helps the government and relevant organisations develop strategies to address environmental hazards and boost the quality of life of the people in the country.

The paper is organised as follows: Section two presents the literature review. Section three discusses the methodological issues, while the results are presented and discussed in Section four. Finally, Section five concludes and provides policy recommendations.

Literature Review

Economic theories have been widely applied to energy, health, and environmental issues. These theories include the Gary production theory, Grossman model, conservative hypothesis, Environmental Kuznets Curve (EKC), and Ramsey-Cass-Koopmans infinitely-lived agent framework. The Gary production theory explains the implications of the interaction between energy consumption and production on infant health-related risks. This theory distinguished between two forms of health and revealed that the first form of health serves as an output in the utility function while the second form enters into the production function as an input (Galama and Kapteyn 2011; Hartwig and Sturm 2018).

The Grossman model considered individuals as consumers and producers of health and argued that health investment would continue until the marginal benefit of health equates to marginal cost. At this equilibrium point, Grossman asserted that the longevity of an individual would be endogenously determined. The model was later integrated into cost analysis to advance collective decision making, and Welfare Theorists demonstrated that societal gains associated with health preservation go a long way in determining the welfare cost for an individual to partake in a collective decision (Shobande and Etukomeni 2018). So, the level of energy consumption coupled with the different policies targeted at improving the living standard of the people is crucial in any nation.

Furthermore, the conservative hypothesis asserted that conservative energy policies boost health outcomes when energy consumption is considered a factor in the health outcomes model (Shobande 2020). The EKC was propounded by Kuznets (1955) to explain the relationship between income inequality and income per capita. The theory was later employed to analyse the different aspects of economic activities. For instance, Grossman and Krueger (1991) used EKC to clarify the relationship between income per capita and two different types of pollution (sulphur dioxide and smoke). Their findings demonstrated that the EKC is an inverted U-shape such that air pollution increases with income per capita at the pre-industrial economies stage through to the industrial economies stage before declining with the income per capita at the post-industrial economies stage. This theory also predicts improvement in environmental conditions as a nation records an increase in the level of economic growth, after which the peak is recorded (Urhie et al. 2020). In summary, health outcomes deteriorate as air pollution increases with income per capita increases but improve after the post-industrial stage.

Empirically, there is still an evolving literature on the relationship among energy consumption, CO_2 emissions and health outcome indicators. The existing empirical studies are divided into cross-countries studies and country-specific studies. For the cross-sectional studies, Adeleye, Azam, and Bekun (2023) employed the structural equation modelling approach to analyse the mediation effect of CO_2 emissions on the nonrenewable energy and infant mortality rate nexus in 42 Asian and Pacific countries between 2005 and 2015. The empirical evidence for the full sample showed that infant mortality rate increases with nonrenewable energy consumption through rising CO_2 emissions. Meanwhile, the results of the different income groups indicated that mediation effects of CO_2 emissions vary.

Using unbalanced panel data on 46 European countries over the period 2005 to 2015, Adeleye et al. (2023) also made an attempt to analyse the effect of CO_2 emissions and non-renewable energy on infant and under-5 mortality rates. The results of their static and dynamic analyses revealed a positive relationship between CO_2 emission and mortality rate and a negative relationship between non-renewable energy and mortality rate. Moreover, the study reported a decline in the absolute value of the positive association of emissions at higher distributions of mortality rates and an increase in the absolute value of the negative association of non-renewable energy at higher distributions of mortality rates.

Sial et al. (2022) used the generalised least square method to analyse the relationship between fossil fuel energy consumption and infant mortality rate in 15 Asian countries from 1996 to 2019. The study established a U-shaped relationship between the consumption of fossil fuel energy and infant mortality in Asian countries. Also, the study submitted that excess fossil fuel energy consumption worsens the standard of living in the Asian countries because of the low air quality levels.

Bouchoucha (2021) assessed the nexus between environmental degradation, health, and institutional quality in 17 Middle East and North African (MENA) countries during 1996 and 2018. Using fully modified ordinary least squares and dynamic ordinary least squares methods, Bouchoucha (2021) reported a negative relationship between health status and environmental degradation in the long run in MENA countries.

Anser et al. (2020) examined the long-run and short-run impact of energy utilisation, greenhouse gasses emissions, and economic activities on mortality rate and incidence of respiratory diseases in emerging Asian economies between 1995 and 2018. This study demonstrated that emissions, fossil fuel consumption, and natural resources depletion have an adverse effect on mortality rate and incidence of respiratory diseases in the long-run while clean energy use and per capita economic growth enhanced households' health status. In the short run, however, the study reported that mortality rate and incidence of respiratory diseases are only affected by greenhouse gasses emission.

Oyelade et al. (2020) employed a quantile regression technique to analyse the effect of environmental quality on people's health in West African Anglophone countries from 1990 to 2013. It is obvious from the results of their study that CO_2 emissions from gaseous and liquid fuel consumption, residential buildings and commercial and public services, solid fuel consumption, and transport negatively affect human health in the region.

In a related study, Shobande (2020) analysed the relationship between energy use and infant mortality rates in 23 African countries between 1999 and 2014. Using the Baseline Pooled Regression and System General Method of Moment, the study specifically examined the impact of energy variables on infant mortality rate and under-5 mortality rates. The results of the study showed that the indicators of energy use have a negative effect on the 23 African countries' infant mortality rates. Also, the empirical evidence suggested that mortality rates increased proportionately with a higher degree of pollution in the countries.

Applying a robust panel fixed effect model, Xing et al. (2019) investigated the impact of fossil energy use and pollutant emissions on public health in 33 countries. Using panel data spanning 1995 to 2015, the results of the analysis showed that fossil energy consumption has a positive impact on life expectancy, while pollutant emissions have a negative relationship with life expectancy.

Osakede and Sanusi (2018) utilised ARDL to analyse the impact of fossil fuel and electricity consumption on life expectancy and infant mortality in Nigeria and South Africa from 1960 to 2014. The study submitted that fossil fuel use and electricity consumption adversely affected life expectancy and infant mortality rates in Nigeria and South Africa. Specifically, the study reported that fossil fuel use and electricity consumption negatively affect infant deaths in Nigeria in the short and long run. Meanwhile, fossil fuel use and electricity consumption only have an adverse effect on health outcomes in the short run for South Africa.

Arawomo, Oyebamiji, and Adegboye (2018) probed the relationship between energy consumption, economic growth, and health outcomes in sub-Saharan Africa (SSA) from 1990 to 2014. The results obtained from the Panel Vector Autoregressive Estimate indicated that economic growth and energy consumption did not significantly impact health outcomes in the selected sub-Saharan African countries. Meanwhile, there was evidence supporting the argument that health care expenditure enhances health outcomes in SSA, while CO_2 emission worsens it. Similarly, Balan (2016) examined the relationship between environmental quality and health outcomes for 25 European Union (EU) member countries from 1995 to 2013. The study established a significant negative relationship between CO_2 emission and health outcomes in the 25 EU countries.

Country-specific studies have also examined the effect of energy consumption and environmental quality on health outcome indicators. For instance, Oyedele (2022) conducted an empirical investigation of the impact of whole and disaggregated CO_2 emission on infant and under-5 mortality rates in Nigeria from 1980 to 2016. It is obvious from the result of the autoregressive distributed lag model and sensitivity analysis that total CO_2 emission has significant impact on both infant mortality and under-5 mortality rates. In addition, the results of the disaggregated analysis showed that CO_2 emissions from solid fuel contributed more to poor health outcomes in Nigeria.

Faizan and Thakur (2019) estimated the impact of household energy consumption on respiratory disease prevalence in India. The study relied on the data obtained from 117,752 respondents diagnosed with different chronic diseases from the 2012 to 2013 District Level Household Survey (DLHS-4). The findings of the study indicated that energy consumption has a very strong impact on respiratory disease prevalence in India, which prompted the conclusion that households using solid fuels are likely to suffer from respiratory diseases.

Using the Dynamic Ordinary Least Square and Granger causality approaches, Afolayan and Aderemi (2019) analysed the impact of environmental quality on the under-5 mortality rate in Nigeria from 1980 to 2016. The study reported an insignificant negative relationship between CO_2 emission and mortality rate. In contrast, the empirical findings revealed that electric power consumption and fossil fuel combustion significantly impact the under-5 mortality rate in Nigeria. Furthermore, the Granger causality test results showed that CO_2 emission Granger causes electric power consumption and government health expenditure; life expectancy Granger causes electric power consumption and government health expenditure; and fossil fuel consumption Granger causes mortality rate.

Matthew et al. (2019) investigated the subject matter using a different approach. They distinguished between various sources of CO_2 emissions and examined their separate effect on health outcomes. Specifically, they utilised an Auto-regressive Distribution Lag model to analyse the impact of CO_2 emissions from construction and manufacturing industries on Nigerians' health conditions from 1985 to 2017. The study submitted that CO_2 emissions from the manufacturing and construction sectors have adverse effects on Nigerians' health conditions.

In a similar study, Nkalu and Edeme (2019) examined the impact of environmental hazards on life expectancy in Nigeria from 1960 to 2017 using Generalised Autoregressive Conditional Heteroscedasticity. The results of the study showed that life expectancy declined with an increase in environmental hazard measured by CO_2 emissions from solid fuel consumption. In other words, an increase in environmental hazards brings about a decrease in the Nigerians' life expectancy.

Just like Nkalu and Edeme (2019) and Matthew et al. (2019), Matthew et al. (2018) probed the long-run relationship between greenhouse gas emissions and health outcomes in Nigeria from 1985 to 2016. The study employed the Auto-regressive Distribution Lag model, and the empirical evidence showed that an increase in greenhouse gas emissions decreases life expectancy. Furthermore, the study demonstrated that the resulting greenhouse gas emissions emanate from the combustion of fossil fuels and CO_2, which are attributable to human activities.

Using a moderated mediation model of economic growth, Urhie, Odebiyi, and Popoola (2017) analysed the relationship between economic growth, air pollution, and health outcomes in Nigeria from 1980 to 2015. The empirical results of the regression path analysis for SPSS-PROCESS showed that government spending and air pollution significantly influenced health performance in Nigeria. In addition, the study reported a significant and plausible relationship between Nigerian economic growth and air pollution, supporting the first stage of the Environmental Kuznets Curve.

Wang (2010) looked at the effect of energy consumption, economic growth, population, and technology progress on China's environment and public health. Wang's model was used to analyse different scenarios between 2010 and 2020. The findings of the study revealed that health damage increases with an increase in particulate matter 10 micrometres (PM-10) and CO_2 emissions in China. Furthermore, the study submitted that energy efficiency, population, economy, and urbanisation are the important drivers.

A detailed review of the relevant studies shows that some issues are unresolved. First, most existing studies conduct cross-country analysis (Adeleye, Azam, and Bekun 2023; Oyelade et al. 2020; Shobande 2020; Xing et al. 2019; Arawomo, Oyebamiji, and Adegboye 2018). Second, mixed results have been reported on the impact of fossil energy consumption on health outcome indicators (Sial et al. 2022; Nkalu and Edeme 2019; Afolayan and Aderemi 2019; Matthew et al. 2019; Xing et al. 2019; Shobande 2020; Arawomo, Oyebamiji, and Adegboye 2018). Third, the studies reviewed analyse the impact of fossil energy consumption and CO_2 emission on different health indicators, including life expectancy, infant mortality rate, and under-5 mortality rate, but the literature is scarce on the impact of these variables on adult mortality rate in Nigeria. This study, therefore, departs from the existing studies by analysing the impact of fossil energy consumption and CO_2 emissions on adult mortality rate in Nigeria. The study chooses these two core independent variables (fossil energy consumption and CO_2 emissions) because they are the key contributors to mortality rate and disease burden globally (Vohra et al. 2021; Farhidi and Mawi 2022; Foye 2022).

Methodology

THEORETICAL FRAMEWORK

The theoretical foundation of this study can be traced to the Health Production Function (HPF), which was first used by Grossman (1972). Or (2000) developed the model to analyse the effect of medical and non-medical inputs, including physical condition and socio-economic factors, on health outcomes. This model has also been used in the existing literature (Arawomo, Oyebamiji, and Adegboye 2018) to investigate the effects of medical and non-medical factors on health outcomes. The baseline function of the health production function is specified as follows:

$$h = f(m, e), \tag{1}$$

where h, m, and e denote health outcomes, medical input, and vector of non-medical indicators, respectively. The HPF predicts a positive relationship between health outcomes and medical inputs or resources. This implies that an increase in health care resources will enhance people's quality of life. However, diminishing returns to scale may also set in after a certain level of resources has been used to support the health care system. On the impact of non-medical input, Or (2000) began his argument by distinguishing between the various non-medical indicators and showed the dissimilarities in the effect of non-medical input such as physical environment, including pollution and socio-economic environment. While water and soil quality may improve health, Or demonstrated that noise and air pollution harm human health.

MODEL SPECIFICATION

This study relies on the health production function in equation (1) to analyse the impact of fossil energy consumption and CO_2 emissions on adult mortality rates in Nigeria. Adult mortality rate is the probability per 1,000 that a 15-year-old will not survive until age sixty. The relationship between fossil energy consumption and mortality rate remains an empirical issue. Vohra et al. (2021) and Anser et al. (2020) claim that fossil energy consumption is associated with high mortality via the air pollution channel. These authors argue that airborne particles and ground-level ozone from fossil energy consumption escalate the mortality and disease burden globally. This is because people that breathe in the polluted air suffer health-wise. Meanwhile, Sial et al. (2022) claim that fossil energy consumption directly and indirectly impacts mortality rates.

The impact of CO_2 emissions on health is well documented in the literature (Oyedele 2022; Vohra et al. 2021; Xing et al. 2016; Du et al. 2016). Jacobson (2008) claims that ozone and airborne particles emanating from higher temperature levels caused by increased CO_2 emissions pose a significant threat to human health and increase mortality rates. Ozone and airborne particles cause and worsen health conditions, including respiratory and cardiovascular illnesses, emphysema, and asthma, among others. This is because airborne particles, even at lower levels of exposure, escape the body's defence, penetrate the respiratory and circulatory system, and damage the lungs, heart, and brain (United Nations 2018).

The study incorporates some control variables into the model. Government expenditure on health is employed to examine the effect of health expenditure on adult mortality rates. Government health expenditure on health facilities and maintenance, as well as health issues, including coronavirus disease (COVID-19), enables healthcare to deliver quality services to the public, prevent the spread of diseases and improve the public health system. Thus, government expenditure is expected to reduce mortality rates (Oladosu, Chanimbe, and Anaduaka 2022; Onofrei et al. 2021; Dhrifi 2018).

Onofrei et al. (2021) and Shobande (2020) point out that high income will enable people to access quality healthcare services and reduce mortality. Moreover, secondary school enrolment is expected to indirectly impact the adult mortality rate because a society populated with educated people records higher income and maintains a decent living standard (Adeleye et al. 2023; Oladosu, Chanimbe, and Anaduaka 2022). Foreign direct investment mortality rate anticipates a direct or indirect relationship. According to Immurana et al. (2023), foreign direct investment brings about technological progress, enabling the receiving country to boost its growth and income level. This, in turn, allows the citizens to access healthcare services and reduce mortality. On the other hand, an inflow of foreign investment may reduce economic growth and lower people's capacity to access quality healthcare. Also, foreign direct investment is associated with air pollution that may affect human mortality in the receiving country (Shah et al. 2022).

The impact of trade openness on mortality rates may be positive or negative. Trade openness can worsen public health and increase mortality when trade policy prevents importing health inputs or boosters, including nutritional goods, beverages, and pharmaceutical drugs. Also, the coming together of businesspeople across the globe may lead to the spread of contagious diseases such as COVID-19 and increase mortality rates. On the other hand, trade openness can reduce mortality when trade policy prevents the import of low-quality products, hazardous materials, and technologies (Byaro, Nkonoki, and Mayaya 2021). Monetary policy may also enhance or impede health outcomes depending on whether the apex bank is pursuing an expansionary or contractionary monetary policy. An expansionary monetary policy enables people to take loans due to lower interest rates and purchase quality medical inputs or services. On the other hand, contractionary monetary policy impedes people's ability to access quality healthcare services (Peter and Adediyan 2020). Based on these augments, the augmented health production function is presented below:

$$amr_t = f(ffc_t, co2_t, gdp_t, geh_t, sse_t, fdi_t, opn_t, mnp_t). \tag{2}$$

Equation (2) is the adult mortality rate model. The econometrics specification of equation (2) with white noise term (μ) is presented in equation (3) as follows:

$$\begin{aligned} \ln amr_t = {} & \beta_0 + \beta_1 ffc_t + \beta_2 \ln co2_t + \beta_3 gdp_t + \beta 4 \ln geh_t + \beta_5 sse_t \\ & + \beta_6 fdi_t + \beta_7 opn_t + \beta_8 mnp_t + \mu, \end{aligned} \tag{3}$$

where ln *amr* is the natural logarithm of adult mortality rate. The medical input is ln *geh* and it stands for the natural logarithm of government expenditure on health. Non-medical indicators include *ffc*, *lnco2*, *gdp*, *sse*, *fdi*, *opn* and *mnp*, which denote fossil energy consumption, natural logarithm of CO_2 emissions, Gross Domestic Product (GDP) per capita growth, school enrolment, foreign direct investment, trade openness, and monetary policy. Since *ffc*, *gdp*, *sse*, *fdi*, *opn* and *mnp* are already in percentage, the study transforms amr, co2 and geh so that all the variables can have the same unit. β_0 denote intercepts and $\beta_1, \beta_2, \ldots, \beta_8$ are the parameters of fossil energy consumption, CO_2 emissions, gross domestic product per capita growth, government expenditure on health school enrolment, foreign direct investment, trade openness, and monetary policy, respectively.

The a priori expectations are expressed mathematically as follows:

$$ffc > 0; \; co2 > 0; gdp < 0; \; geh < 0; \; sse < 0;$$

$fdi < / > 0; \; opn < / > 0; \; mnp < / > 0.$

ESTIMATION TECHNIQUES

The study examines the descriptive statistics of the variables and conducts a multicollinearity test using a correlation matrix. To establish the order stationarity of the variables, the study uses the Augmented Dickey-Fuller (ADF) unit root test and authenticates the results using the Philip-Perron unit root test. Moreover, the study utilises the Autoregressive Distributed Lag (ARDL) Bounds test to ascertain the long-run equilibrium property of the variables in the model. Also, it estimates the adult mortality model using the ARDL technique developed by Pesaran, Shin, and Smith (2001). ARDL is suitable for a model with order one variables or combinations of order zero and order one. Also, it performs better with a small sample size of data (Romilly, Song, and Liu 2001). It is also suitable for estimating the speed of adjustment from the short-run disequilibrium to the long-run equilibrium (Foye 2023) and the dependent variable must not be I(2) to satisfy the assumption of ARDL (De Vita, Klaus, and Lester 2006; McNown, Sam, and Goh 2018). The ARDL representation $(p, q, r, s, t, u, v, w, x)$ of equation (3) is presented below:

$$\begin{aligned}
\Delta \ln amr_t = \beta_0 &+ \sum_{i=1}^{p} \beta_1 \Delta \ln amr_{t-1} + \sum_{i=1}^{q} \beta_2 \Delta ffc_{t-1} \\
&+ \sum_{i=1}^{r} \beta_3 \Delta \ln co2_{t-1} + \sum_{i=1}^{s} \beta_4 \Delta gdp_{t-1} \\
&+ \sum_{i=1}^{t} \beta_5 \Delta \ln geh_{t-1} + \sum_{i=1}^{u} \beta_6 \Delta sse_{t-1} \\
&+ \sum_{i=1}^{v} \beta_7 \Delta fdi_{t-1} + \sum_{i=1}^{w} \beta_8 \Delta opn_{t-1} \\
&+ \sum_{i=1}^{x} \beta_9 \Delta mnp_{t-1} + \alpha_1 \ln amr_{t-1} + \alpha_2 ffc_{t-1} \\
&+ \alpha_3 \ln co2_{t-1} + \alpha_4 gdp_{t-1} + \alpha_5 \ln geh_{t-1} + \alpha_6 sse_{t-1} \\
&+ \alpha_7 fdi_{t-1} + \alpha_8 opn_{t-1} + \alpha_9 mnp_{t-1} + \mu_t. \qquad (4)
\end{aligned}$$

Equation (4) is the unrestricted intercept and no trend. The first difference operator is represented by Δ, β_0 is the drift component of the model and μ is the error term. The error term is expected to behave well, that is, be serially independent, homoscedastic and normally distributed. $\beta_1, \beta_2, \ldots, \beta_9$ are the short run parameters while $\alpha_1, \alpha_2, \ldots, \alpha_9$ are the long-run coefficients.

To estimate the long-run relationship, the study normalises (Alsamara et al. 2019) the long-run coefficients by dividing them by the coefficient of the first lag of *logamr* (α_1). The long-run model can be written as follows:

$$\begin{aligned} \ln amr_t = {} & +\alpha_0 + \alpha_1 ffc_{t-1} + \alpha_2 \ln co2_{t-1} + \alpha_3 gdp_{t-1} + \alpha_4 \ln geh_{t-1} \\ & + \alpha_5 sse_{t-1} + \alpha_6 fdi_{t-1} + \alpha_7 opn_{t-1} + \alpha_8 mnp_{t-1} + \mu_t, \end{aligned} \tag{5}$$

where $\alpha_1, \alpha_2, \ldots, \alpha_8$ are the long-run parameters, α_0 is constant, and μ is the white noise. The study specifies the following error correction model to estimate the short-run relationship:

$$\begin{aligned} \Delta \ln amr_t = {} & \beta_0 + \sum_{i=1}^{p} \beta_1 \Delta \ln amr_{t-1} + \sum_{i=1}^{q} \beta_2 \Delta ffc_{t-1} \\ & + \sum_{i=1}^{r} \beta_3 \Delta \ln co2_{t-1} + \sum_{i=1}^{s} \beta_4 \Delta gdp_{t-1} \\ & + \sum_{i=1}^{t} \beta_5 \Delta \ln geh_{t-1} + \sum_{i=1}^{u} \beta_6 \Delta sse_{t-1} \\ & + \sum_{i=1}^{v} \beta_7 \Delta fdi_{t-1} + \sum_{i=1}^{w} \beta_8 \Delta opn_{t-1} \\ & + \sum_{i=1}^{x} \beta_9 \Delta mnp_{t-1} + \varphi ecm_{t-1} + \mu, \end{aligned} \tag{6}$$

where Δ is the first difference operator, β_0 is the intercept, $\beta_1, \beta_2, \ldots, \beta_9$ are the short run estimates, φ is the speed of adjustment from short-run disequilibrium to long-run equilibrium, ecm_{t-1} is the error correction term lagged one time and μ is the white error term. Moreover, the study conducts post estimation tests, including the Breusch-Godfrey Serial Correlation LM test, Breusch-Pagan-Godfrey Heteroscedasticity test, Jarque-Bera Normality test, Cumulative Sum of Recursive Residual (CUSUM) and Cumulative Sum of Squares (CUSMSQ) to check the robustness of the model.

SOURCES AND MEASUREMENT OF DATA

The study investigates the effect of fossil energy consumption and CO_2 emissions on adult mortality rate in Nigeria using time series data from

TABLE 1 Definition and Measurement of Variables, Data Sources, and A Priori Expectations

Variables	Symbol	Definition and Measurements	Sources
Adult mortality rate (per 1,000 adults)	*amr*	This is the probability per 1,000 that 15-year-old persons will not survive till age sixty.	WDI
Fossil fuel energy consumption (% of total)	*ffc*	This is the sum of all oil, petroleum, natural gas, and coal products and it is measured as a percentage of total energy use.	WDI
CO_2 emissions (kt)	*co2*	This occurs as a result of the burning of fossil fuels and the manufacture of cement. It is the sum of all the emissions produced during consumption of solid, liquid, and gas fuels and gas flaring. This is measured in kilotons.	WDI
GDP per capita growth (annual %)	*gdp*	Gross domestic product per capita growth is gross domestic product divided by midyear population. It is the annual percentage growth rate of GDP per capita based on constant local currency.	WDI
Health expenditure	*ghe*	This is the government expenditure on health facilities and it is measured in billion naira. It is proxied by total recurrent expenditure on health.	CBN
School enrolment (% gross)	*sse*	School enrolment is the ratio of total enrolment, regardless of age, to the population of the age group that officially corresponds to the level of education. It is the percentage of gross enrolment.	WDI

Continued on the next page

1980 to 2019. The variables, definition and measurement, symbol, and data sources are presented in table 1.

Empirical Results

PRELIMINARY ANALYSIS

Table 2 reports the summary statistics of the adult mortality rate (*amr*), fossil energy consumption (*ffc*), CO_2 emissions (*co2*), gross domestic product per capita growth (*gdp*), government health expenditure (*ghe*), secondary school enrolment (*sse*), foreign direct investment (*fdi*), trade openness (*opn*) and monetary policy (*mnp*). The average adult mortality rate (per 1,000 live births) is 389.43. This is bigger than the mean value of 287.5 for Sub-Saharan African (SSA) countries' adult mortality by 101.93 (World Bank N.d.). The implication of this result is that 389.43 deaths of

TABLE 1 *Continued from the previous page*

Variables	Symbol	Definition and Measurements	Sources
Foreign direct investment, net inflows (% of GDP)	*fdi*	Foreign direct investment combines all equity capital, reinvestment of earnings, and other capital flowing into Nigeria and it is measured as a percentage of gross domestic product.	WDI
Openness (% of GDP)	*opn*	This is the sum of exports and imports of goods and services measured as a share of gross domestic product.	WDI
Monetary policy (money supply (annual %))	*mnp*	This is also called broad money and it is the annual growth rate of the currency outside banks.	WDI

NOTES WDI stands for World Development Indicators (https://data.worldbank.org/country/nigeria) and CBN is the Central Bank of Nigeria (https://www.cbn.gov.ng/documents/statbulletin.asp).

TABLE 2 Descriptive Statistics

Item	*amr*	*ffc*	*co2*	*gdp*	*ghe*	*sse*	*fdi*	*opn*	*mnp*
Mean	389.43	19.52	87407.53	0.49	73.59	31.076	0.33	32.71	23.85
Max	413.20	22.84	115280.0	12.28	388.37	56.21	1.92	53.28	87.76
Min	363.72	15.85	42441.86	−15.70	0.04	10.97	−0.02	9.14	−0.79
SD	13.60	1.55	17192.89	5.25	103.17	10.08	0.45	12.51	18.23
Obs	40	40	40	40	40	40	40	40	40

NOTES The mean is also known as average, max stands for maximum, min is minimum, SD represents standard deviation and obs stands for observation.

adults occur for every 1,000 live births in Nigeria. This is alarming compared to the SSA countries, where only 287.5 deaths occur for every 1,000 live births. This supports the argument in the literature that Nigeria has high mortality rates.

A close look at table 2 shows the mean value of fossil energy consumption is 19.52. Compared to the average consumption of 39.8 in SSA, this implies that Nigeria contributes about 20 percent to the 39.8 percent of fossil energy consumption in SSA. This is not unexpected as Nigerian sectors and households rely on oil, natural gas, and other forms of fossil fuel for daily production and consumption activities. The mean value of CO_2 emissions is 87,407.53 kilotons, while CO_2 emissions in SSA revolve around 823,770 kilotons. The average mean value of CO_2 emissions is high for Nigeria compared to SSA, suggesting that Nigeria is one of

TABLE 3 Multicollinearity Results

Variables	*logamr*	*ffc*	*logco2*	*gdp*	*logghe*	*sse*	*fdi*	*opn*	*mnp*
logamr	1								
ffc	0.09	1							
logco2	−0.21	−0.25	1						
gdp	0.06	−0.22	0.34	1					
logghe	−0.46	−0.49	0.77	0.44	1				
sse	−0.72	−0.39	0.59	0.32	0.77	1			
fdi	0.33	0.20	−0.24	0.00	−0.10	−0.15	1		
opn	0.23	−0.22	0.46	0.50	0.55	0.16	0.21	1	
mnp	0.33	0.06	−0.01	0.17	−0.002	−0.20	0.28	0.32	1

NOTES The highest correlation coefficient between two independent variables is 0.77, which suggests that the independent variables are free from the problem of multicollinearity.

the high-emitting countries in SSA. This is corroborated by the high gas flaring and CO_2 emissions in Nigeria. This finding is in line with the submission of Adesete, Olanubi, and Dauda (2022) that Nigeria is the second highest gas-emitting country in SSA. Moreover, the mean value of GDP per capita growth in Nigeria is 0.49 percent, which is very low compared to the average value of 1.6 percent recorded in SSA. The implication is that economic growth does not translate to higher income in Nigeria. This cannot be far from the truth because Nigeria is the most populous country in Africa and characterised by income inequality. Government health expenditure prints a mean of 73.59 billion. This result implies that the Nigerian government spent an average of 73.59 billion on maintaining healthcare centres in Nigeria between 1980 and 2019. The mean of secondary school enrolment of 31.076 percent is close to the 44 percent recorded in SSA. This places Nigeria as one of the countries with a high secondary school enrolment rate in SSA. Furthermore, the mean values of foreign direct investment, trade openness, and monetary policy are 0.33, 32.71, and 23.85 percent, respectively. Moreover, table 3 shows that each of the correlation coefficients is less than 0.80, the rule of thumb (Kim 2019), suggesting that the variables are not collinear.

STATIONARY TEST

Macroeconomic time series are susceptible to nonstationarity, causing regression results to suffer from spurious regression problems (Gu-

TABLE 4 Unit Root Test

Variable	ADF		PP		Order of integ.
	(1)	(2)	(1)	(2)	
logamr	−1.11 (0.92)	−4.89 (0.00)***	−1.15 (0.91)	−4.83 (0.00)***	I(1)
ffc	−3.39 (0.07)*	–	−3.5 (0.05)*	–	I(0)
logco2	−4.12 (0.01)**	–	−4.06 (0.01)**	–	I(0)
gdp	−2.45 (0.35)	−11.73 (0.00)***	−4.13 ((0.01)**	−21.29 (0.00)***	I(1)
logghe	−0.01 (0.99)	−5.40 (0.00)***	−3.78 (0.03)**	−22.22 (0.00)***	I(1)
sse	−2.43 (0.36)	−7.65 (0.00)***	−2.45 (0.35)	−7.65 (0.00)***	I(1)
fdi	−7.96 (0.00)***	–	−4.03 (0.02)**	–	I(0)
opn	−3.28 (0.08)*	–	−3.55 (0.05)**	–	I(0)
mnp	−3.73 (0.03)**	–	−3.74 (0.03)**	–	I(0)

NOTES Cpulumn headings are as follows: (1) level, (2) first difference. ADF is Augmented Dickey-Fuller and PP stands for Phillips-Perron. The two unit root test were conducted using constant & trend and Schwarz Info Criterion. *, ** and *** denote significance at 10%, 5% and 1%, respectively. Probability values in parentheses.

jarati 2004). The study utilises the Augmented Dickey-Fuller (ADF) and Phillip-Perron (PP) unit root tests to avert this problem. Two unit root tests are chosen to obtain robust results since the stationarity property of the variables is a prerequisite for the ARDL estimation.

A variable is stationary at level, that is, I(0) if the ADF/PP test statistic is bigger than the critical values. Otherwise, it is I(d), where d represents the number of times the series is differenced before it becomes stationary. The results presented in table 4 indicate that *logamr*, *gdp*, and *logghe* are stationary at the first difference, that is, I(1), while *ffc*, *logco2fdi*, *opn*, and *mnp* are stationary at level, that is, I(0). This mixed stationary justifies the use of the ARDL technique.

ARDL BOUNDS CO-INTEGRATION TEST

Having established the stationary properties, the study estimates the ARDL Bounds model to show the long-run relationship between the variables. The ARDL bounds test is based on the *F*-statistics value with the null hypothesis of no long-run relationship and an alternate hypothesis of cointegration. The null hypothesis of no cointegration is rejected if the calculated *F*-statistic is greater than the lower and upper bound critical value. However, the result will be inconclusive if the calculated *F*-statistic is bigger than the lower bound and less than the upper bound critical

TABLE 5 ARDL Bounds Test Result

F-Bounds Test		Null Hypothesis: No levels relationship		
t-statistic	Value	Significance	I(0)	I(1)
F-statistic	6.45	10%	1.95	3.06
K	8	5%	2.22	3.39
		2.5%	2.48	3.70
		1%	2.79	4.10

NOTES ARDL Bounds test reveals that the variables are co-integrated in the long-run. I(0) denotes lower bound and I(1) denotes upper bound. Lag length is 2.

values (Pesaran, Shin, and Smith 2001). The result of the ARDL bounds test presented in table 5 indicates that the value of the *F*-statistic is bigger than the values of the Lower I(0) and Upper bounds I(1). This result indicates a long-run relationship between the variables. In other words, the variables are co-integrated in the long run.

INTERPRETATION OF THE SHORT-RUN AND LONG-RUN RESULTS

The results presented in table 6 show that fossil energy consumption has an insignificant negative impact on adult mortality rates in the short run. However, a one percent increase in the first lag of fossil energy consumption significantly decreases adult mortality rates by 0.00256 percent in the short-run, ceteris paribus. CO_2 emissions exert a positive and significant relationship with adult mortality rates. Holding other variables constant, a one percent increase in CO_2 emissions increases the number of adult deaths per 1,000 people in Nigeria by 0.02642 percent in the short run. GDP per capita growth and government health expenditure exert no significant impact on adult mortality. The first lag of government health expenditure increases adult mortality rates. Given that all other predictor variables in the model remain at a fixed value, adult mortality rates increase by 0.00491 for every one percent increase in the first lag of government health expenditure in the short-run.

Moreover, the short-run results reveal that secondary school enrolment has no significant impact on adult mortality. Likewise, there is no significant relationship between foreign direct investment and adult mortality rates. Meanwhile, the first lag of foreign direct investment is positive and significant in the short run. This implies that a one percent increase in foreign direct investment lagged one time reduces deaths of adults per

TABLE 6 Short-Run and Long-Run Results

Group	Variable	Coefficient	t-Statistics	Probability
Short run estimates	*d*(*ffc*)	−0.00110	−0.92120	0.3691
	d(*ffc*(−1))	−0.00256	−2.68771	0.0150**
	d(*logco2*)	0.02642	2.49829	0.0224**
	d(*gdp*)	0.00020	0.74977	0.4631
	d(*logghe*)	−0.00178	−1.08891	0.2906
	d(*logghe*(−1))	0.00491	2.74249	0.0134**
	d(*sse*)	−0.00023	−0.81777	0.4242
	d(*fdi*)	−0.00067	−0.22019	0.8282
	d(*fdi*(−1))	−0.00797	−2.79046	0.0121**
	d(*opn*)	−0.00024	−1.42592	0.1710
	d(*opn*(−1))	0.00021	1.35978	0.1907
	d(*mnp*)	−0.00005	−0.80376	0.4320
	cointeq(−1)	−0.18288	−2.34622	0.0306**
Long run estimates	*ffc*	0.00210	0.32715	0.7473
	logco2	0.14445	2.67043	0.0156**
	gdp	0.00445	2.06100	0.0541*
	logghe	−0.01938	−2.93211	0.0089***
	sse	−0.00123	−1.04263	0.3109
	fdi	0.05704	1.84123	0.0821*
	opn	−0.00024	−0.20008	0.8437
	mnp	−0.00025	−0.75983	0.4572
	C	4.33923	6.76430	0.0000***

NOTES 1%, 5% and 10% significant levels are denoted by ***, **, and *, respectively.

TABLE 7 Robustness Checks

Item	*F*-statistics	Probability
Heteroscedasticity Test: Breusch-Pagan-Godfrey	0.61734	0.8424
Breusch-Godfrey Serial Correlation LM Test	1.26751	0.3083
Jarque-Bera Stat	0.12276	0.9405

1,000 persons by 0.00797 percent in Nigeria, provided all other predictors are fixed.

Furthermore, the results show that trade openness and monetary policy exert an insignificant negative impact on adult mortality rates in Nigeria. Also, there is no significant relationship between the first lag of trade openness and adult mortality rates in Nigeria.

In the long-run, fossil energy consumption is positive and insignificant. CO_2 emissions and GDP per capita growth have a significant positive impact on adult mortality rates. Holding other variables constant, a one percent increase in CO_2 emissions and GDP per capita growth lead to a 0.14445 and 0.00445 percent increase in adult mortality rates in Nigeria, respectively. Also, there is a significant negative relationship between government health expenditure and adult mortality. This implies that adult mortality decreases by 0.01938 percent for every one percent increase in government health expenditure in Nigeria, based on the condition that all other predictor variables in the model remain the same. Moreover, foreign direct investment has a significant positive impact on adult mortality rates. By implication, a one percent increase in foreign direct investment increases adult mortality rates by 0.05704 percent, after controlling for the other predictors in the model. Secondary school enrolment, trade openness, and monetary policy are negative and insignificant in the long run.

The value of the error correction term is less than one, negative, and significant. This supports the earlier conclusion that the variables are co-integrated in the long run (Foye 2023). Also, the coefficients suggest that a temporary disequilibrium in the system will be corrected annually at a speed of 0.18288 percent until the steady-state is attained. Finally, the post estimation results reveal that the residual of the model is normally distributed and free from the problems of serial correction and heteroscedasticity.

DISCUSSION OF THE EMPIRICAL RESULTS

It is obvious from the results presented in table 6 that the fossil energy consumption (first lag) has a significant negative impact on adult mortality rate in the short run, though it is positive and insignificant in the long run. The negative short run relationship negates the a priori expectation and the submission of Vohra et al. (2021) and Anser et al. (2020), who report that fossil energy consumption contributes to higher mortality. Meanwhile, the result conforms to the work of Sial et al. (2022), who find a U-relationship between fossil energy consumption and mortality rates. Although the coefficient is quite small (0.00256), the implication is that fossil energy consumption reduces adult mortality rate in the short run in Nigeria. This means the economic benefits associated with fossil energy consumption outweigh its adverse effect on adult mortality in the short run. In other words, fossil energy consumption does not immediately contribute to higher adult mortality in Nigeria. The airborne particulate matter and ground-level ozone from fossil energy consumption do not immediately escape the adult body's defence as with new-borns and young children. Also, these results could be attributed to the fact that adults do not breathe quickly and absorb more pollutants emanating from fossil energy consumption more rapidly, as with children (United Nations 2018). Meanwhile, as fossil energy consumption grows, the adverse effects become more apparent on adults as shown by the positive relationship in the long run.

CO_2 emissions increase the adult mortality rates in Nigeria both in the short and long run. These findings agree with the a priori expectation and also lend credence to Oyedele (2022), Vohra et al. (2021), Oyelade et al. (2020), and Shobande (2020), who submit that CO_2 worsens human health in Nigeria. CO_2 emissions contribute greatly to outdoor air pollution, a significant threat to human health, and increase adult mortality rates in Nigeria. In addition, the findings strengthen the position of international organisations such as the World Health Organisation and climate-based organisations that often promote the consumption of clean energy to enhance the quality of life of Nigerians.

Onofrei et al. (2021) and Shobande (2020) assert that income, also known as GDP per capita growth, will enable people to afford healthcare services and improve their standard of living. But the case is not the same for Nigeria as the study establishes a significant positive relationship between GDP per capita growth and mortality rates in the long run. Though this finding contradicts the a priori expectation and substantial part of the literature, it conforms to the submission of Rasoulinezhad, Taghizadeh-Hesary, and Taghizadeh-Hesary (2020) and Farooq, Yusop, and Chaudhry (2019), who also report that income increases mortality rate. The implication of this finding is that a higher GDP per capita growth does not translate to public health improvement in Nigeria. One possible explanation for this is income inequality. This suggests that as GDP per capita increases, the gap between the rich and the poor may increase, leading to a rise in relative poverty for some of the population. This, in turn, could lead to a rise in mortality rates, as people living in poverty tend to have poorer health outcomes due to limited access to healthcare. Nigeria is an energy-oriented country, relying heavily on fossil fuels as its major source of income (Foye 2023). Fossil fuels, which constitute the larger part of the total energy consumption, are a major source of air pollution that harms human health globally.

In the short run, the behaviour of the first lag of government health expenditure contracts the theoretical prediction. Also, the finding disagrees with the conclusion of Oladosu, Chanimbe, and Anaduaka (2022) that an increase in heath expenditure improves public health. However, the finding is in line with Azuh et al. (2020), who prove that government health expenditure increases mortality rate in Nigeria. The adverse effect of government health expenditure can be attributed to mismanagement, a nonchalant government attitude toward the health sector and high level of corruption that has bedevilled the Nigerian economy (Azuh et al. 2020; Olaifa and Benjamin 2019). Though government health expenditure adversely affects human health in the short run, there is evidence that the government adjusts and addresses the factors limiting the effectiveness of the health fund in the long run. As reported in table 6, government health expenditure has a significant negative effect on adult mortality rates in Nigeria. This implies that the government health fund improves human health. This finding conforms to a priori expectation and supports the findings of Onofrei et al. (2021) and Dhrifi (2018). This long-run result is not a surprise considering the renewed efforts of the international organisations, including USAID, to ensure that the Nigerian government pays important attention to the health sector.

Foreign direct investment has a U-shape relationship with adult mortality in Nigeria. In the short run, the one lag of foreign direct investment reduces adult mortality rates in Nigeria. This finding is corroborated by Immurana et al. (2023), who submit that foreign direct investment improves human health. Inflow of foreign direct investment to Nigeria brings about technology progress, improve firms' productivity, and enables people to earn a higher income and improve their standard of living (Immurana et al. 2023). In the long run, foreign direct investment increases adult mortality in Nigeria. This finding is in line with the result of Shah et al. (2022), who claim that foreign investment harms human health. Inflow of foreign investment directly results in an increase in firms' production capacity. Given the fact that Nigeria is an energy-oriented country, the consumption of fossil energy increases with the increase in production and this affects the air quality. The poor air quality leads to different diseases and increases the adult mortality rates in Nigeria.

Trade openness and monetary policy are insignificant in the short and

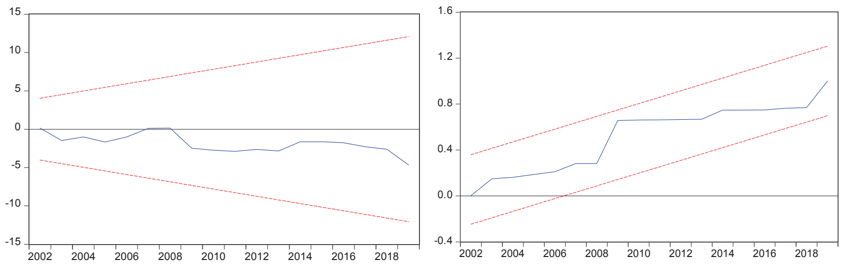

FIGURE 1 CUSUM (left) and CUSUMSQ (right) of Adult Mortality Rates (blue – CUSUM/CUSUMQ, red – 5% significance)

long run. The implication is that there is insufficient evidence to suggest that trade openness and monetary policy affect adult mortality rates in Nigeria between 1980 and 2019. These findings are incongruous to the submission of Byaro, Nkonoki, and Mayaya (2021) and Peter and Adediyan (2020), who claim that trade openness and monetary policy have significant impact on adult mortality rates. To establish the relative impact of fossil energy consumption and CO_2 emissions, the study follows Olofin et al. (2014) by examining the magnitude of the estimated model. It is obvious from the results that the magnitude of CO_2 emissions is greater than the magnitude of energy consumption. This implies that effort should be channelled towards decreasing fossil energy usage or encouraging consumption of environmentally friendly energy to improve health quality in Nigeria. Finally, the study assesses the constancy of the parameters using the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ). As shown in figure 1, the plots of the CUSUM and CUSUMSQ of the model are within the 5 percent critical bounds of parameter stability. Hence, the study concludes that the parameters are stable.

Conclusion and Policy Implications

This study analyses the short-run and long-run impact of fossil energy consumption and CO_2 emission on adult mortality rates in Nigeria from 1980 to 2019. The study controls for government health expenditure, gross domestic product per capita growth, school enrolment, foreign direct investment, trade openness, and monetary policy and utilises ADF and PP unit root tests to establish their stationary property. The ARDL technique is used for the analysis, and the results of the estimated model show that fossil energy consumption reduces adult mortality rates in the short run, suggesting that the economic benefit associated with fossil energy consumption outweighs its adverse effect on adult mortality in Nigeria. On the other hand, CO_2 emissions increase the adult mortality rate in the short and long run. This proves that outdoor air pollution associated with CO_2 emissions poses a significant threat to healthy living in Nigeria.

Moreover, the study finds that GDP per capita growth harms human health in the long run. This is justified by the heavy reliance of Nigeria on fossil energy as a major income source. Government health expenditure follows an inverted U-shape relationship in explaining adult mortality while foreign direct investment has a U-shape relationship with adult mortality in Nigeria. Trade openness and monetary policy are insignificant in the short and long run. The relative analysis indicates that CO_2 emissions have more impact on adult mortality compared to fossil energy consumption.

Overall, it is recommended that the government should substitute clean energy for fossil fuel energy to improve the quality of life in Nigeria since the magnitude of CO_2 emissions on adult mortality is greater than the magnitude of fossil energy consumption in the estimated models. Also, fossil energy consumption should be controlled by strengthening CO_2 emissions tax and channelling the funds to the health sector. Moreover, the government should increase the health fund and ensure the funds are used for the improvement of healthcare service delivery in Nigeria. Considering the impact of income and foreign direct investment, further policy initiatives should encourage the consumption of clean energy in Nigeria.

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Is Climate Finance Helping Stabilise Food Prices in Sub-Saharan Africa?

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This study explores the potential impact of climate finance (CF) on food prices in Sub-Saharan Africa (SSA) as climate change continues to create food scarcity and increase food prices. The study analyses data from 43 SSA countries between 2006 and 2018 using a panel fixed effect model with Driscoll-Kraay standard errors and methods of moments quantile regressions (MMQR). The findings indicate that countries in SSA that receive more CF, improve their fight against corruption, have good rainfall patterns, experience reduced extreme temperatures, have depreciated currencies, larger populations and higher GDP growth, reduce food imports, increase domestic food supply, and demonstrate high governance and social readiness are likely to experience stable or reduced food prices. Based on these results, the study recommends that SSA governments prioritise anti-corruption efforts to earn donor trust and increase CF, ultimately leading to lower food prices in the sub-region. Further, the findings indicate that good rainfall patterns reduce food prices: this shows the need for SSA countries to invest in policies that lead to reliable water supply as irrigation.

Key Words: climate finance, food prices, climate change, Sub-Saharan Africa
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Introduction

Climate change is expected to drive an increase in global food prices over the next decade, predominantly due to the anticipated decline in food crop yields arising from rising temperatures and erratic rainfall patterns in various regions around the world (Espitia, Rocha, and Ruta 2020). This development is likely to aggravate the risk of food insecurity for many people (Parkes, Sultan, and Ciais 2018). The Food and Agriculture Organization of the United Nations (n.d.) has already noted a decrease in food production, attributed to climate variability, extremes, conflicts, and economic slowdowns. Furthermore, several global crop and economic models predict an increase in cereal prices of up to 29% by 2050, attributable to climate change (Mbow et al. 2019; Agyei et al. 2021), which is expected to have a deleterious effect on consumers. Nevertheless, the severity of the impact is predicted to vary across regions, with those in low-income countries being at a greater risk.

According to Mbow et al. (2019), approximately 183 million more people may face food insecurity by 2050 due to climate change. Food prices in Sub-Saharan Africa (SSA) are typically tied to agricultural yields, with prices falling during bumper harvests and rising during droughts. Although SSA countries contribute minimally to climate change, they are extremely vulnerable to its adverse effects. As most of the region's population relies on crops sensitive to climate conditions, extreme weather events and rising temperatures could undermine cereal production (Thornton et al. 2011; Knox et al. 2012; Buhaug 2015). Nyiwul (2021) estimates that a temperature rise of 2.5°C could result in a USD 23 billion reduction in Africa's net farming revenue by 2030, causing major staple prices to increase by 10–60%, and poverty rates to rise by 20–50% in certain parts of the continent. Additionally, rainfall variability in the tropical and eastern SSA regions is expected to rise by 7%, potentially leading to substantial flooding and reducing cereal yields in the sub-region by at least 5%. Failure to consider the impact of climate change on food prices could make it difficult to achieve Sustainable Development Goal (SDG) 2 target 2.1, which seeks to ensure access to adequate, nutritious, and safe food for all individuals by 2030 (Reardon et al. 2019; Agyei et al. 2021).

Against the backdrop of increasing vulnerability to climate change in SSA, the twenty-first session of the Conference of Parties (COP21) to the United Nations Framework Convention (UNFCCC), known as the Paris Agreement of 2015, urged developed countries to raise climate funds of at least USD 100 billion per year from 2020. These funds were intended to support developing countries in mitigating and adapting to climate change, reducing vulnerability, and building human and ecological resilience. Although some climate finance has been raised over the last decade, the 2020 target of USD 100 billion was not met and has now been postponed to 2023, as proposed by COP26. Regrettably, SSA remains one of the most vulnerable sub-regions globally, with over 226.7 million people in Africa suffering from starvation, mainly due to dwindling food production and rising food prices caused by scarcity. This situation is exacerbated by the fact that between 40 to 50 percent of people in the region live below the poverty line, with incomes below USD 1.25 a day. The African Development Bank (AfDB) estimates that climate change adaptation costs, expressed as a percentage of GDP, are higher for SSA, hovering around 1.7–1.8%, relative to 1.3–1.4% for other regions in the world. Moreover, SSA is estimated to require at least USD 20–30 billion per year until about 2030 to help mitigate and adapt to climate change.

Studying the impact of climate change and finance on rising food prices in SSA is crucial for several reasons. Firstly, many countries in SSA are net-food importing countries and are thus susceptible to food price spikes. According to Compton, Wiggins, and Keats (2010), who employed the climate change vulnerability index and high price risk index compiled from 30 sub-indicators, 25 out of 35 SSA countries are among the most vulnerable countries in the world in terms of vulnerability to food price surges. This situation threatens economic, social, and physical access to safe, nutritious, and sufficient food by the poor in the region. Secondly, although SSA has contributed only 4% of total greenhouse gas emissions, it is the region that is expected to suffer most from the exacerbating impact of climate change, due to the relationship between climate change, agricultural output, food prices, and extreme weather that collectively endangers food security in the region. SSA is projected to need USD 50 billion per year from 2050 to mitigate and adapt to climate change, but between 2003–2017 had only received a total of USD 3.6 billion for 506 projects and programmes.

A persistent rise in food prices can be considered as food inflation. Most prior studies on food inflation or food price stability believe it is caused by an increase in money supply (monetarist theorists such as Stamoulis, Chalfant, and Rausser 1985; Frankel 1986; Friedman and Schwartz 2008; Iddrisu and Alagidede 2020; Kaur 2021; Mahmoudinia 2021), exchange rate and crude oil prices (Alper, Hobdari, and Uppal 2016; Mahmoudinia 2021), and COVID-19 (Agyei et al. 2021). Some studies added to this debate by arguing that the major drivers of food inflation in developing countries are poor provision of social safety nets and subsidies by government, infrastructure underdevelopment (like poor roads and no silos), and inefficient foreign trade networks (Devereux 2006; Odongo et al. 2022). Some theorists blame climate change and weather variability as major causes of food inflation, since climatic shocks disrupt food production, processing, availability, and access (Sen 1981; Ericksen 2008; Odongo et al. 2022; Iliyasu, Mumman, and Ahmed 2023).

This article extends the discussion by finding an answer to the following question. If SSA countries receive the needed financial support to mitigate and adapt to climate change (climate finance), and to develop its underdeveloped infrastructure, will it lead to stable food prices in the sub-region? This paper contributes to current knowledge on the mitigation and adaptation to climate change literature in three ways. (1) To the best of our knowledge, this is the first study to uncover the impact of climate adaptation and mitigation finance on food prices. (2) It establishes the climate finance-food inflation relationship in one of the most climate vulnerable regions in the world, i.e. SSA. (3) It shows whether SSA governments are socially, economically or governance or ready to use climate finance for mitigating and adapting to climate change.

Based on that, this study seeks to find out whether the climate finance so far received is helping stabilise food prices in the region expected to be worst hit by climate change. Climate finance (CF) is a fund pledged by developed countries to provide an amount of money to help developing countries mitigate and adapt to climate change (Doku, Ncwadi, and Phiri 2021a). The findings show that climate finance has a significant food price reduction effect in the face of stronger control of corruption in SSA. Governance readiness to mitigate and adapt to climate change showed a significant food price reduction effect in SSA. The study recommends that SSA governments establish stronger control of corruption to win the trust of CF donors and motivate them to increase the amount of funds extended to the sub-region. Further, more CF should be extended to areas in SSA with higher temperature shocks to protect them from food insecurity and enable a reduction in food prices.

In the next section we review relevant extant literature. This is followed by the model specification and estimation technique. In the fourth section we present findings, while the final section provides conclusions and recommendations based on the study's results.

Brief Literature Review

In this section, the study briefly looks at theoretical and empirical literature related to the topic under study.

THEORETICAL LITERATURE

Climate finance is widely recognised as a form of international aid that provides support to vulnerable countries, particularly those in Sub-

Saharan Africa, to mitigate and adapt to the impacts of climate change. Previous studies, including Doku, Ncwadi, and Phiri (2021a; 2021b), Doku, Richardson, and Essah (2022), Doku and Phiri (2022), and Doku (2022), have examined the potential of climate finance to address food insecurity in these regions. In this study, we explore the relationship between food aid and food prices by drawing on investment theory and modernisation theory (Bezuneh and Deaton 1997).

Investment theory suggests that foreign aid can help stabilise food prices by providing budget support and increasing foreign exchange reserves in recipient countries. As aid is received by central governments, it can boost their revenue base and stimulate aggregate demand within their respective economies. Additionally, aid can be used to support the production of climate-resistant agricultural commodities at reduced prices, and to establish domestic buffer stocks to stabilise food prices during times of economic instability. This can serve as an important safety net for the most vulnerable populations during economic downturns, as noted by Bezuneh and Deaton (1997) and Doku, Richardson, and Essah (2022). Furthermore, food aid is more effective and accessible than aid in the form of financial resources, as it can be easily directed by households, particularly mothers, for the benefit of children and elderly family members.

The theory of investment is further elaborated by modernisation theory, which asserts that developed and developing countries can benefit from trade relationships (Frijns, Phuong, and Mol 2000; Dunford 2023). Developing countries can gain access to export markets, capital, and technology needed for development, while developed countries can acquire cheaper raw materials, investment opportunities, and markets for their products. Modernisation theorists suggest that opening up the global economy can redirect factors of production to their most efficient use, leading to productivity gains and positive spillover effects in developing economies. This process has the potential to equalise development levels and real wages, and stabilise input prices in the global economy. In light of these perspectives, climate finance, as a form of aid, should be expected to reduce or stabilise food prices.

EMPIRICAL LITERATURE REVIEW

Upon careful analysis of the existing literature, it was found that food inflation is influenced by several factors, such as a country's monetary policy, crude oil prices, exchange rate, and climate variability and extremes (Aron et al. 2014; Mejía and Garcia-Diaz 2018; Akanni 2020; Kaur 2021;

Dalheimer, Herwartz, and Lange 2021; Köse and Ünal 2022; Eregha 2022; Kunawotor et al. 2022; Fernandes 2023; Iliyasu, Mamman, and Ahmed 2023). Some drivers of food prices have been reported in extant literature to include heavy reliance on biofuels, conflict, climate variability and extremes, and economic slowdowns and downturns (Mejía and Garcia-Diaz 2018; Food and Agriculture Organization of the United Nations n.d.; Kaur 2021; Okou, Spray, and Unsal 2022). Other studies have found population growth to have put pressure on demand for food and food prices (Barrett 1999; Mizdrak et al. 2015), monetary policy (Barth and Ramey 2001; Chowdhury, Hoffmann, and Schabert 2006; Gaiotti and Secchi 2006; Henzel et al. 2009; Iddrisu and Alagidede 2021; Eregha 2022; Fernandes 2023), exchange rate (Abbott, Hurt, and Tyner 2008; Aron et al. 2014; Nakamura and Zerom 2010; Norazman, Khalid, and Ghani 2018; Okou, Spray, and Unsal 2022), oil prices (Rosegrant 2008; Mitchell 2008; Nazlioglu and Soytas 2012; Davidson et al. 2011; Louw 2017; Norazman, Khalid, and Ghani 2018; Bala and Chin 2018; Fasanya and Akinbowale 2019; Lidiema 2020; Agyei et al. 2021; Köse and Ünal 2022; Eregha 2022) and international trade (Abbott, Hurt, and Tyner 2008; Giordani, Rocha, and Ruta 2016; Okou, Spray, and Unsal 2022). Literature review of this study will be analysed in two ways: (1) Climate change and food price, and (2) Climate finance and food price in SSA.

Several prior studies in the food security literature have indicated a worsening effect of climate change on food prices for countries most dependent on the agricultural sector (Lobell et al. 2008; Cooper et al. 2008; Deressa et al. 2009; Thornton et al. 2009; Hertel and Rosch 2010; Ringler et al. 2010; Di Falco and Veronesi 2011; Claessens et al. 2012; Wheeler and Braun 2013; Wossen et al. 2014; Wossen et al. 2018; Tumushabe 2018; Sam, Abidoye, and Mashaba 2021). Climate change influences food prices through agricultural yield, as periods of bumper harvest will see food prices dropping, whereas food prices soar during lean seasons (Nelson et al. 2014; Valin et al. 2014; Robinson et al. 2014; Schmitz et al. 2012; Mbow et al. 2019). Climate change will cause a reduction in food availability, which will lead to a rise in food cost that translates into higher food prices. This will lead to a reduction in the purchasing power of low-income consumers, such as SSA, who are particularly at risk from higher food prices (Nelson et al. 2010; Nelson et al. 2018; Springmann et al. 2016; Mbow et al. 2019). Okou, Spray, and Unsal (2022) estimated that natural disaster shocks like climate change increase food prices by 1.8 percent, whereas wars increase food prices by 4 percent on average in SSA. Higher food prices suppress consumer demand, which leads not only to a reduction in energy intake, but also a reduction in available healthy diet (Hasegawa et al. 2015; Hasegawa et al. 2018; Nelson et al. 2010; Nelson et al. 2018; Springmann et al. 2016). This in turns increases the rate of diet-related mortality in lower and middle-income countries, such as SSA (Springmann et al. 2016).

Ringler et al. (2010) employed climate circulation models to project the impact of climate change on food prices up to the year 2050. They projected that climate change will reduce cereal production (foremost is wheat, followed by millet, sorghum and rice) in the coming decades. As a result, prices of staple crops are bound to increase under climate change scenarios. Climate change is expected to cause a hike in the prices of staple crops, the reason being that climate change acts as an additional stressor on the already tightening price outlook. Further, they projected that climate change will cause maize, rice, and wheat prices in 2050 to rise by 4, 7, and 15 percent more as compared to the historic climate scenario (Doku, Richardson, and Essah 2022).

Heavy investment in climate-smart agriculture by developing countries will help ameliorate the intertwined problem of climate change and food security globally. Based on the Copenhagen accord of 2009, developed countries pledged to raise climate finance to help developing countries mitigate and adapt to climate change, especially in the agricultural sector. The accord proposed a fast-start finance of USD 30 billion for the period 2010–2012. Although USD 35 billion was raised above this commitment value, only USD 0.75 billion (representing 2.1%) was disbursed to the agricultural sector (Doku, Ncwadi, and Phiri 2021a; 2021 b; Doku, Richardson, and Essah 2022; Doku 2022).

Doku, Ncwadi, and Phiri (2021b) posited that the impact of climate finance on environmental degradation follows a U curve known as the climate finance effect (climfin effect). Climfin effect shows that as countries receive CF in the initial stages, environmental degradation may worsen as countries look for ways to mitigate and adapt to climate change. As time goes on, they will find sustainable ways to do so, leading to a reduction in environmental degradation. In this study, we also postulate a climfin effect on food prices in SSA in that, as countries receive CF in a quest to mitigate and adapt to climate change during the initial stages, environmental degradation worsens due to increased agricultural activities and deforestation. This will begin to show a food price reduction due to increase in agricultural output. After some time, the necessary technology is adopted to mitigate and adapt to climate change. As a result, CF will begin to reduce food prices to represent price stability. Other studies such as Amadu, McNamara, and Miller (2020) looked at climate finance (by focusing on climate finance from USA-USAID) on agricultural yield in Malawi. They found that climate finance increases maize yield by 53 percent, which is likely to help reduce food prices.

Data and Methodology

DATA

The research question raised at the outset of this study is to find out the impact of climate finance on food prices in SSA. To achieve that, data collected covers 43 SSA countries (refer to table 7 for selected countries) over a period of 13 years, from 2006 to 2018. A total of 15 variables are employed in this study, based on extant literature and the objective of the study. The variables are made up of a dependent variable, i.e. food price (FP), and 14 independent variables. The independent variables are climate finance (CF), control of corruption (COC), rainfall, temperature, Forex, population, GDP per capita growth (GDP*growth*), international trade (*Trade*), aid, foreign direct investment (FDI), urbanisation, economic readiness (*Ereadiness*), social readiness (*Sreadiness*) and governance readiness (*Greadiness*). Table 1 presents how the variables are measured and their sources.

The descriptive statistics from table 2 show that FP in SSA increased

TABLE 1 Data Description and Sources

Variable	Description	Source
FP	Yearly food price inflation in percentage	FAOSTAT
CF	Climate finance commitment data, mitigation and adaptation finance data (Constant 2018 USD)	OECD-DAC climate-related development finance
COC	Is a coefficient from 0 to 1 that measures people's perception of how public power is exercised for private gains	World Bank Climate Change Knowledge Portal (WBCCKP)
Rainfall	Mean annual rainfall for each country in millimetres	World Bank Climate Change Knowledge Portal (WBCCKP)
Temperature	Mean annual temperature for each country in centigrade	WBCCKP

Continued on the next page

TABLE 1 *Continued from the previous page*

Variable	Description	Source
Forex	Standard local currency units per USD	FAOSTAT
Population	The headcount of people living in a country at a particular time or year in millions	FAOSTAT
GDP*growth*	GDP per capita growth (at constant 2018 USD)	World Development Indicators (WDI)
Trade	Value of food imports in total merchandise exports (percent)	FAOSTAT
Aid	Overseas Development Assistance per capita (Constant 2018 USD) extended to SSA	WDI
FDI	Foreign direct investment, net flows to SSA (Constant 2018 USD thousand)	WDI
Urbanisation	Percentage of a country's population living in urban areas	WDI
Ereadiness	Economic readiness is a coefficient ranging from 0 to1 computed by ND-GAIN using 'ease of doing business' index.	ND-GAIN
Sreadiness	Social readiness is a coefficient ranging from 0 to 1 compiled by ND-GAIN using four main indicators: education, social inequality, Information Communication Technology (ICT) and innovation	ND-GAIN
Greadiness	ND-GAIN measured governance readiness is a coefficient ranging from 0 to 1 using four main indicators: political stability and non-violence, control of corruption, regulatory quality and rule of law	ND-GAIN

NOTES Data from FAOSTAT was solicited from https://www.fao.org/faostat/en/#data, CF from https://www.oecd.org/dac/financing-sustainable-development/development-finance-topics/climate-change.htm, WDI from Indicators | Data (worldbank.org), ND-GAIN from https://gain.nd.edu/our-work/country-index/download-data/.

by 7.6 percent on average during the period under consideration. Sudan had the highest food inflation of 69.25 percent in 2018. This can be attributed to various factors, such as widespread conflict and droughts afflicting the country. The primary independent variable in this study is climate finance (CF). Descriptive statistics show that CF flows to SSA countries averaged USD 199.3 million, with countries like Ethiopia receiving as high as USD 2.4 billion in 2018. Control of corruption (COC) value shows an average of 0.273, which signifies weak corruption control of SSA gov-

TABLE 2 Descriptive Statistics

Variable	Mean	SD	Min	Max
1. FP	7.64	8.37	−10.88	69.25
2. CF	199.30*	284664.70	59.8*	2.40**
3. COC	0.27	0.14	0.00	0.67
4. *Rainfall*	89.66	51.16	7.05	273.50
5. *Temperature*	25.36	11.38	12.98	29.80
6. *Forex*	$1.25e^{7}$	$2.90e^{9}$	0.91	$6.72e^{10}$
7. *Population*	21.31	30.36	0.50	195.90
8. GDP*growth*	2.13	4.40	−36.83	18.88
9. *Trade*	54.66	118.79	0	775.00
10. *Aid*	70.74	70.21	0.46	663.71
11. FDI	$8.47e^{8}$	$1.60e^{9}$	$-7.40e^{9}$	$1.00e^{10}$
12. *Urbanisation*	40.76	17.16	9.62	88.98
13. *Ereadiness*	0.24	0.12	0	0.67
14. *Sreadiness*	0.22	0.05	0.09	0.34
15. *Greadiness*	0.39	0.12	0.17	0.67

NOTES * million, ** billion.

ernments, apart from Botswana, that scores 0.66 for corruption control. Additionally, two climate change variables were employed to investigate how climate change is affecting food price variability in SSA. These variables include rainfall and temperature. The average rainfall for the study period was 89.66 millimetres, while the average temperature was 25.36 centigrade for SSA. For the macroeconomic variables, GDP per capita growth for SSA averaged 2.132 and the population averaged 21.31 million for the study period. Trade data shows that most of the countries in SSA are net exporters of food, with a mean value of 54.66%. In addition, Aid and FDI for SSA averaged 70.74 million and 874 million, respectively, for the study period. The descriptive statistics further show that 40.74 percent of people in SSA live in urban areas. Although the readiness variables are very poor, Greadiness seems to be better on average (0.386) as compared to Ereadiness (0.24) and Sreadiness (0.22).

MODEL AND ESTIMATION TECHNIQUE

Most prior studies in the food price literature identified factors such as economic growth, climate change, international trade, currency markets, oil prices, natural disasters and government policies as major drivers of food prices (Odongo et al. 2022; Okou, Spray, and Unsal 2022). Some studies argue that food price variation largely depends on population growth and agricultural output or food supply availability. In order to reduce the problem of multicollinearity in the models, we omitted oil prices because it is a factor that highly correlates with exchange rate (Forex) and international trade (Trade) variables.

The main focus of this study is to complement the climate change-food inflation literature by arguing that if developing countries receive enough CF with stringent corruption control by governments, CF could be used to increase agricultural output through mitigation and adaptation to climate change. A major problem serving as a bane of the development of developing countries is corruption in governance. As CF is received, low corruption levels will mean CF is put to good use to stabilise food prices through yield. This will lead to reduction in food prices due to bumper harvests and improvement in food security. Control of corruption (COC) is thus included in the model to cater for good governance.

In that vein, we include climate finance (CF), control of corruption (COC) and climate variables (Rainfall and Temperature) in models 1 through 4. This is to find out whether the impact of CF on food price (FP) could be distorted by introducing the domestic and external factors. This study differs from prior studies by including the CF variable to the baseline model. This is done to find out whether CF is helping stabilise or reduce food prices, and thus

$$\mathrm{FP}_{it} = \beta_1 + \beta_2\mathrm{CF}_{it} + \beta_3\mathrm{COC}_{it} + \beta_4 Rainfall_{it} + \beta_5 Temperature_{it} + \mu_t + e_{it}, \tag{1}$$

where β_1 denotes country-specific effects and μ_t is a vector of time-specific effects. Climate variables (Rainfall and Temperature) were included in the model in line with studies by Nguyen et al. (2017) and Odongo et al. (2022), to capture the variability in food supply leading to higher food prices. We project that improved rainfall will lead to a reduction in food prices, whereas high fluctuation in temperature and rainfall will drive food prices up.

$$\begin{aligned}\mathrm{FP}_{it} = {} & \beta_1 + \beta_2\mathrm{CF}_{it} + \beta_3\mathrm{COC}_{it} + \beta_4 Rainfall_{it} + \beta_5 Temperature_{it} \\ & + \beta_6 Forex_{it} + 7 Population_{it} + 8\mathrm{GDP}growth_{it} \\ & + \beta_9 Trade_{it} + \mu_t + e_{it}.\end{aligned} \tag{2}$$

In model (2), we introduced other macroeconomic independent variables (*Forex*, *Population*, GDP*growth* and *Trade*) into the baseline model. This is done to cater for country-specific characteristics that contribute to cross-country differences in food price increases (Okou, Spray, and Unsal 2022; Odongo et al. 2022).

Forex is expected to influence food prices through the import channel of international trade (Abbot, Hurt, and Tyner 2008). Periods of currency depreciation will experience an increase in food prices, while appreciation reduces food prices.

GDP*growth* is included in the model because Odongo et al. (2022) intimate that increases in real GDP signify increases in real money balances, which may lower food prices. On the other hand, higher GDP could be driven by higher imported goods, likely to drive food prices up.

Food import is included to cater for intermediate and finished agricultural products purchased from foreign countries. Imported inflation theory postulates that higher prices of imported goods will drive up local food prices. Trade is measured in terms of food import, consistent with the study of Giordani, Rocha, and Ruta (2016) and Madito and Odhiambo (2018): a country which is a net exporter of food will have a value below 100, whereas a country which is a net importer of food will have a value above 100.

$$\begin{aligned}\mathrm{FP}_{it} = {} & \beta_1 + \beta_2\mathrm{CF}_{it} + \beta_3\mathrm{COC}_{it} + \beta_4 Rainfall_{it} + \beta_5 Temperature_{it} \\ & + \beta_6 Forex_{it} + \beta_7 Population_{it} + \beta_8 \mathrm{GDP}growth_{it} \\ & + \beta_9 Trade_{it} + \beta_9 Aid_{it} + \beta_{10}\mathrm{FDI}_{it} + \beta_{11} Urbanization_{it} \\ & + \mu_t + e_{it}. \end{aligned} \tag{3}$$

According to the UN framework Convention on Climate Change (UNFCCC), CF is any transnational, national or local financing raised from private, public or alternative sources of financing with a goal to help mitigate and adapt to climate change (Doku, Richardson, and Essah 2022; Doku 2022). This means that CF can be raised through aid, loans and foreign direct investment (FDI). As a result, we estimated a third model (model 3) to find out whether FDI will have a similar impact on food prices. We also included urbanization in model (3), computed as the percentage of a country's population living in urban areas, as Okou, Spray, and Unsal (2022) established that within-country variation for food prices is 2.4% lower in large cities, and this urban-rural price gap is wider for imported foods. It is established that standard of living and cost of living is higher in urban compared to non-urban areas, so food prices are expected to be higher in urban areas.

In the final model (4), we tried finding out which area of readiness, i.e. governance readiness (Greadiness), economic readiness (Ereadiness) and social readiness (Sreadiness) in mitigating and adapting to climate change has the potential to stabilise or reduce food prices in SSA.

$$\begin{aligned} \text{FP}_{it} = {} & \beta_1 + \beta_2\text{CF}_{it} + \beta_3\text{COC}_{it} + \beta_4 Rainfall_{it} + \beta_5 Temperature_{it} \\ & + \beta_6 Forex_{it} + \beta_7 Populationit + \beta_8\text{GDP}growth_{it} \\ & + \beta_9 Trade_{it} + \beta_9 Aid_{it} + \beta_{10}\text{FDI}_{it} + \beta_{11} Urbanization_{it} \\ & + \beta_{12} Ereadiness_{it} + \beta_{12} Greadiness_{it} + \beta_{12} Sreadiness_{it} \\ & + \mu_t + e_{it}. \end{aligned} \quad (4)$$

To test the presence of multicollinearity in our model, we employed Pearson's product-moment cross correlation (results presented in table 3). Ibrahim, Ahmed, and Minai (2018) asserted that correlation between independent variables below 0.8 is acceptable. Independent variables with a correlation coefficient greater than 0.8 mean that one of the variables should be dropped from the same regression model. Most of the variables did not show high correlation, apart from COC and Greadiness, which produces a correlation coefficient of close to 0.8.

A challenge confronting panel data series is cross-sectional dependence in a situation where the cross-sectional units are not randomly sampled, hence the series will depend on unobserved and observed disturbance terms (Özokcu and Özdemir 2017; Sarkodie and Strezov 2019; Sarkodie and Adams 2020; Doku, Ncwadi, and Phiri 2021b). This is the case of this study: 12 out of the 15 variables employed in this study showed cross-sectional dependence (refer to table 6). To circumvent this problem, the Driscoll and Kraay (1998) algorithm is employed, which accounts for cross-sectional dependence, yielding consistent and robust estimated standard errors.

Secondly, the Driscoll-Kraay algorithm assumes that the error structure is heteroscedastic and autocorrelated to some lag length (Sarkodie and Strezov 2019). As shown in table 4, there exists autocorrelation and heteroscedasticity in each model estimated. Furthermore, the Driscoll-Kraay estimator is nonparametric and flexible, without many restrictions imposed on the limiting behaviour of the number of panels. Thirdly, in situations of missing data points in a series, it has the ability to handle it, implying that it works effectively in both balanced and unbalanced panel situations, which is the case in this study (Sarkodie and Adams 2020).

To better understand the Driscoll-Kraay error structure in our models, the error structure in equations (1)–(4) is modified to have a lagged cross-sectional and contemporaneous and lag structure represented as Driscoll and Kraay (1998) and Sarkodie and Adams (2020):

$$\mu_{it} = \psi_i Y_t + \nu_{it}, \text{ where} \tag{5}$$

$$Y_t = \rho Y_{t-1} + \varepsilon_{it}. \tag{6}$$

Here, the forcing terms are represented as ν_{it} and ε_{it} with a mean of zero. As explained by Sarkodie and Adams (2020), forcing terms are explained as uncorrelated mutually independent variables over time and across units in a series. There exists cross-sectional dependence in the error structure in the presence of an unobserved factor Y_t common across units.

Given that the Driscoll-Kraay panel regression deals with only the conditional mean of FP, robustness of the estimates was carried out using the novel method of moment quantile regression (MMQR) of Machado and Santos Silva (2019) in order to control for the distributional heterogeneity inherent in the estimated regression. Notably the MMQR model is robust in handling fixed effects in panel quantile models. It also enables the estimation of other aspects of the conditional distribution. In this study, the 25th, 50th and 75th percentiles are used for regression, as proposed by Adeleye et al. (2021). The basic model of the MMQR by Machado and Santos Silva (2019) is specified as:

$$y = \beta X + \theta X\, x\, \varepsilon, \tag{7}$$

where β represents the location effect, which looks at how the conditional mean of y ($E(y|X)$) will change when X changes; θ represents the scale effect, for it measures how much the distribution expands away or contracts closer to the conditional mean. A positive value of θ shows that an increase in X will cause the variance of the error to increase. A combination of the scale and location effect yields the conditional quantile coefficient. Following the study by Machado and Santos Silva (2019) and Adeleye et al. (2021), we specify the general form of the conditional quantile regression of the location-scale variant model as:

$$q_{\text{EM}}(\tau|X_{it}) = (\alpha_i + \delta_i qi) + X_{it}^l + Z_{it}^l \gamma q(\tau). \tag{8}$$

Equation (8) is assumed to be a linear model, where $q_{\text{EM}}(\tau|X_{it})$ denotes the quantile distribution of the explained variable conditional on the location of the independent variables, X_{it}^{l} denotes a vector of all independent variables of the study, $\alpha_i(\tau) = \alpha_i + \delta_i q(\tau)$ is the scalar coefficient of the quantile-τ fixed effect for individual l, Z^l signifies a k-vector of known differentiable transformations of the components of X, and finally, $q(\tau)$ shows the τ-th quantile derived from optimising the following function:

$$\min_{q} \sum_{i} \sum_{t} \rho_\tau(\hat{R}_{it} - (\hat{\delta}_i + Z_{it}^{l}\hat{\gamma})q), \tag{9}$$

in a way that, $\rho_\tau(A) = (\tau - 1)AI\{A \leq 0\} + \tau AI(\{A > 0\})$ denotes the check-function.

Findings

This section of the study presents the empirical results derived from the panel fixed effect regression analysis with Driscoll-Kraay standard errors. The selection of the Driscoll-Kraay algorithm was necessitated by the presence of heteroscedasticity and autocorrelation inherent in the models, as indicated in table 4. Furthermore, a Hausman test was conducted to determine whether to employ fixed effect or random effect models. Based on the results, we opted for the fixed effect model.

The outcomes of table 4 indicate that CF has a food-price reduction effect with a level of significance of 5 percent. Specifically, the results demonstrate that a dollar increase in CF reduces food prices by at least 0.03 cents in SSA for all three models, implying that CF has contributed to improved food access through lower food prices in SSA. This may be attributed to the fact that over 80 percent of the nationally determined contributions by most developing countries are geared towards agricultural management. In addition, climate-smart agricultural technologies are the target of most climate funds. This is expected to increase the agricultural yield of most beneficiary countries, which in turn reduces food prices due to bumper harvests. Therefore, it can be stated that CF has yielded positive results in the agricultural sector in SSA, which confirms the dictates of the climfin effect proposed by Doku, Ncwadi, and Phiri (2021a) and is consistent with both investment and modernisation theories. Other CF variables included in the model – aid and FDI – did not show any significant impact on food prices.

The findings regarding COC align with the results of the first three models, indicating a significant food price reduction effect in SSA for the first three models. This suggests that SSA countries striving to control corruption are better positioned to utilise climate funds effectively, leading to increased agricultural yield and reduced food prices.

Regarding the climate variables, rainfall had a significant impact on food prices across all four models, while temperature only had a significant effect in the first two models. The results suggest that regions in SSA with regular and increased rainfall are able to increase agricultural yield and reduce food prices, whereas areas with high temperatures experience drought and reduced crop yield, resulting in higher food prices. This result is consistent with the findings of Reardon et al. (2019), Agyei et al. (2021) and Odongo et al. (2022). This result indicates that good rainfall patterns reduce food prices in SSA, since good rainfall patterns support good harvests, particularly of food crops. Odongo et al. (2022) asserted that significance of rainfall patterns in food price determination explains why we need to prioritise investment in policies that lead to reliable water supply like irrigation and reinforced water storage facilities in all households. Further, a significant positive impact of temperature on food prices indicates that areas with higher temperatures in SSA are more likely to experience higher food inflation. This result is consistent with several prior studies, including Odongo et al. (2022). This is because higher temperature represents increased drought, which is likely to cause crop failure and bush burning in SSA, which translates into lower food production and increased food prices due to scarcity. This finding shows that climate finance targeted at reducing food prices and ensuring food security in SSA should focus more on areas with temperature shocks compared to areas with rainfall shocks.

Furthermore, Forex had a significant negative impact on food prices across all four models, indicating that as the value of the currency of SSA countries depreciates or devalues, food prices stabilise or decline. This result contradicts previous studies, such as Iddrisu and Alagidede (2020) for South Africa and Okou, Spray, and Unsal (2022), but is consistent with some trade theories that explain why China devalues its currency to sell goods at cheaper prices.

Population was found to have a significant negative impact on food prices, indicating that countries with a higher population sell food at lower prices. This could be attributed to the fact that most SSA countries with higher populations are home to the poor, who have lower living standards and cost of living, which translates to lower food prices. Interestingly, this contradicts previous literature, where an increase in population growth was found to increase demand and push prices upward (Gilbert

TABLE 3 Cross Correlation

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. FP														
2. CF	−0.084													
3. COC	−0.077	0.005												
4. *Rainfall*	0.045	−0.128	−0.452											
5. *Temperature*	−0.002	0.018	−0.095	0.017										
6. *Forex*	−0.032	−0.014	−0.050	−0.037	−0.012									
7. *Population*	0.231	0.136	−0.144	−0.064	0.225	−0.012								
8. GDP*growth*	0.111	0.087	0.138	−0.059	−0.081	−0.220	0.107							
9. *Trade*	−0.101	−0.084	0.208	−0.217	0.026	−0.012	−0.178	0.083						
10. *Aid*	−0.096	−0.112	0.442	−0.088	−0.035	−0.013	−0.283	0.054	0.553					
11. FDI	0.038	0.019	−0.034	−0.026	0.086	−0.022	0.558	0.056	−0.147	−0.139				
12. *Urbanisation*	−0.208	−0.063	0.025	0.164	0.067	−0.019	−0.151	−0.014	0.275	0.082	0.115			
13. *Ereadiness*	0.036	0.068	0.480	−0.164	−0.096	0.012	−0.009	0.164	−0.005	0.086	0.177	0.044		
14. *Sreadiness*	−0.107	0.114	−0.050	0.190	0.115	−0.110	−0.105	−0.040	0.063	0.183	−0.068	0.156	−0.07	
15. *Greadiness*	−0.117	0.002	0.782	−0.202	−0.129	−0.081	−0.207	0.143	0.152	0.345	0.008	0.138	0.720	0.060

2010). Additionally, GDP growth was found to have a significant negative impact on food prices, implying that SSA countries experiencing higher economic growth are seeing a reduction in food prices. This could be attributed to the fact that as countries grow through industrialisation and increased production, they begin to enjoy economies of scale, leading to reduced production costs and prices.

This result harmonises with several prior studies, including Odongo et al. (2022) and Okou, Spray, and Unsal (2022). This finding is consistent with the theory linking GDP and inflation; this could mean that the source of the increased GDP is primarily from non-tradeables as opposed to tradeables. The findings further indicate that an upsurge in GDP shows a rise in food availability, which translates into reduced food prices.

Trade had a significant positive impact on food prices, which is consistent with the findings of Giordani, Rocha, and Ruta (2016) and Odongo et al. (2022). The variable used to compute trade is import per merchandised export, indicating that food prices rise as SSA countries increase import of food and reduce as SSA countries produce enough food to export excess. This could be attributed to the fact that the cost of producing agricultural commodities in SSA is cheaper compared to other countries due to favourable weather conditions and cheap labour. Further, the results indicate the influence of external cost-push factors on domestic agricultural prices. This shows a strong transmission of foreign prices via imported goods to overall inflation of a country and trickles down to food prices. For policy, this result is signalling a need for countries in the sample to invest heavily in food self-sufficiency programmes rather than relying on imported goods.

Lastly, we sought to investigate whether SSA countries' readiness to mitigate and adapt to climate change is helping reduce food prices. Table 4 provides compelling evidence that governance readiness (Greadiness) is the principal readiness variable that, when strengthened, results in a reduction in food prices. Our findings reveal that SSA countries that prioritise reducing corruption, upholding the rule of law, and enhancing institutional quality – as represented by Greadiness – are more likely to decrease food prices. Sreadiness and Ereadiness showed a food price reduction effect, but not significant. This may be due to the weak attention given to them by SSA governments. As a result, we suggest that policies should be geared towards improving the ease of doing business index of Ghana to reduce food prices.

TABLE 4 Fixed Effect Panel Regression with Driscoll-Kraay Standard Errors

Variables	Model 1	Model 2	Model 3	Model 4
CF	−0.116**	−0.0822**	−0.0359*	−0.0391*
	(0.0408)	(0.0312)	(0.0314)	(0.0319)
COC	−9.418*	−9.734*	−22.100***	7.217
	(4.781)	(4.940)	(6.320)	(14.840)
Rainfall	−0.0875***	−0.114***	−0.123***	−0.122***
	(0.019)	(0.021)	(0.023)	(0.023)
Temperature	0.017**	0.052***	−3.431	−3.663
	(0.007)	(0.011)	(3.645)	(3.548)
Forex		$-5.23e^{-10}$***	$-6.14e^{-10}$***	$-6.73e^{-10}$***
		($1.19e^{-10}$)	($1.20e^{-10}$)	($1.14e^{-10}$)
Population		−0.359*	−0.062	−0.035
		(0.164)	(0.153)	(0.190)
GDP*growth*		−0.165***	−0.147***	−0.140***
		(0.0467)	(0.030)	(0.030)
Trade		0.0157**	−0.0199	−0.0244
		(0.00499)	(0.0168)	(0.0176)
Aid			0.0175	0.0188
			(0.013)	(0.012)
FDI			$-1.14e^{-10}$	$-8.39e^{-10}$
			($2.41e^{-10}$)	($2.15e^{-10}$)
Urbanisation			−0.960***	−0.499
			(0.229)	(0.424)
Ereadiness				−11.010
				(11.990)
Sreadiness				−93.030
				(54.610)
Greadiness				−35.430*
				(16.600)

Continued on the next page

At the end we assess the impact of climate finance on the distribution of food prices across different percentiles (25th, 50th, and 75th percentiles). Table 5 presents the location and scale function estimates, alongside the quantile regression estimates.

TABLE 4 *Continued from the previous page*

Variables	Model 1	Model 2	Model 3	Model 4
Constant	18.120***	27.890***	147.100	158.800*
	(1.825)	(3.358)	(87.760)	(85.340)
R_2	0.0258	0.0670	0.1142	0.1385
Wooldridge test (auto-correlation): *p*-value	0.0008	0.0007	0.0004	0.0002
Modified Wald test (hetero.): *p*-value	0.0000	0.0000	0.0000	0.0000

NOTES Driscoll-Kraay Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

TABLE 5 Method of Moment Quantile Regression Result

Variables	Location	Scale	25th	50th	75th
CF	−0.0335*	0.0197*	−0.0796*	−0.0396*	−0.0452*
	(0.0865)	(0.0783)	(0.0528)	(0.0721)	(0.0705)
COC	4.764	3.070	−10.47*	−3.822*	3.897
	(7.579)	(6.859)	(6.490)	(6.316)	(5.284)
Rainfall	−0.00989*	−0.00277*	−0.0131*	−0.00903*	0.0148*
	(0.0149)	(0.0135)	(0.0137)	(0.0124)	(0.0164)
Temperature	0.484**	−0.0914	0.432**	−0.456**	−0.505
	(0.243)	(0.220)	(0.181)	(0.202)	(0.334)
Forex	$-1.50e^{-9}$*	$-1.42e^{-9}$*	$-4.45e{-10}$	$-1.06e^{-9}$	$-2.76e^{-9}$
	($8.20e^{-10}$)	($7.42e^{-10}$)	(0.000450)	($6.82e^{-10}$)	(0.00109)
Population	0.0465	0.00817	0.0297*	0.0440*	0.0502
	(0.0300)	(0.0272)	(0.0162)	(0.0250)	(0.0393)
GDP*growth*	0.118	0.0563	0.0259	0.101	0.0684
	(0.148)	(0.134)	(0.160)	(0.123)	(0.174)

Continued on the next page

We assumed a linear scale function for the MMQR model to allow for a comparison with the results of the Driscoll-Kraay panel fixed-effect regression. The MMQR results suggest that the extension of climate finance to SSA has the potential to reduce food prices across all quantiles. The results for rainfall indicate that moderate levels of rainfall are associated with a significant reduction in food prices, but very high levels of rainfall (i.e. 75th percentile) may not help stabilise food prices, possibly due to flooding and destruction of farms associated with extreme rainfall. Over-

TABLE 5 *Continued from the previous page*

Variables	Location	Scale	25th	50th	75th
Trade	0.00487	0.00140	0.00260	0.00444	0.00327
	(0.0134)	(0.0122)	(0.0130)	(0.0112)	(0.0215)
Aid	0.0109	0.00292	0.00517	0.00998	0.0248**
	(0.0124)	(0.0112)	(0.0158)	(0.0103)	(0.0126)
FDI	$-5.15e^{-10}$	$-4.44e^{-10}$	$2.16e^{-10}$	$-3.78e^{-10}$	$-7.84e^{-10}$
	$(3.67e^{-10})$	$(3.32e^{-10})$	$(3.08e^{-10})$	$(3.05e^{-10})$	$(5.95e^{-10})$
Urbanisation	−0.0389	−0.0488	−0.0138	−0.0239	0.00757
	(0.0461)	(0.0417)	(0.0362)	(0.0384)	(0.0678)
Ereadiness	14.17	9.749	3.669	11.18	9.152
	(10.41)	(9.421)	(5.699)	(8.665)	(10.81)
Sreadiness	−0.957	−7.866	1.000	1.457	−39.28
	(20.61)	(18.65)	(9.497)	(17.18)	(26.62)
Greadiness	−24.50*	−21.52*	−13.59	−17.89*	−31.15***
	(12.52)	(11.33)	(10.09)	(10.38)	(10.36)
Constant	24.47***	15.08**	13.87**	19.84***	34.44***
	(7.340)	(6.642)	(6.010)	(6.086)	(9.519)
Observations	298	298	298	298	298

NOTES Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

TABLE 6

Variable	CD-test	*p*-value	Variable	CD-test	*p*-value
FP	22.369	0.000	*Trade*	0.466	0.641
CF	1.767	0.077	*Aid*	9.649	0.000
COC	1.445	0.148	FDI	10.229	0.000
Rainfall	7.511	0.000	*Urbanisation*	77.36	0.000
Temperature	52.888	0.000	*Ereadiness*	4.058	0.000
Forex	50.178	0.000	*Sreadiness*	75.474	0.000
Population	96.898	0.000	*Greadiness*	0.945	0.345
GDP*growth*	8.170	0.000			

NOTES The Pesaran CD test is based on the null hypothesis of cross-sectional dependence.

all, the majority of the MMQR results align with those of the panel fixed-effect regression with Driscoll-Kraay standard errors.

TABLE 7 List of Sub-Saharan African Countries Employed

Angola	Congo, Rep.	Madagascar	Senegal
Benin	Côte d'Ivoire	Malawi	Sierra Leone
Botswana	Equatorial Guinea	Mali	Seychelles
Burkina Faso	Ethiopia	Mauritania	South Africa
Burundi	Gabon	Mauritius	South Sudan
Cameroon	Gambia	Mozambique	Tanzania
Cape Verde	Ghana	Namibia	Togo
Central Africa Rep.	Guinea-Bissau	Niger	Uganda
Chad	Kenya	Nigeria	Zambia
Comoros	Lesotho	Rwanda	Zimbabwe
Congo, Dem. Rep.	Liberia	Sao Tome and Prin.	

Conclusion

In this study, fixed effect panel regression with Driscoll-Kraay standard errors was utilised to assess the influence of climate finance (CF) on food prices in 43 Sub-Saharan African (SSA) countries from 2006 to 2018, and the results were corroborated using the MMQR estimator. This paper adds to the climate change-food inflation literature by finding out whether climate finance so far received by SSA is helping mitigate and adapt to climate change. This is expected to increase food production, which is expected to reduce food prices in SSA. The main setback to this level of analysis is that climate change is a long-term phenomenon which is difficult to measure in models of this form, so the results should be considered with some care.

The outcomes demonstrate that CF has a food price reduction and stability effect in SSA for all models and estimators employed. This may be so because investment in climate-smart agriculture and technology are major targets of CF. As the agriculture sector booms via increased yields, it is expected to push food prices downward. Linked to CF results is the control of corruption (COC) variable. It showed that SSA countries receiving CF and fighting corruption strongly are the ones experiencing a reduction in food prices. In addition to making efforts to attract more climate funds by governments in SSA, they should also enact policies to make corruption expensive. Another setback of this study is that aid and FDI did not show any significant impact on food prices. This is because total aid and FDI data was used; aid and FDI data geared toward climate mitigation and adaptation may prove otherwise.

For the climate variables, stable rainfall patterns show a food price reduction effect in SSA. This result indicates that good rainfall patterns reduce food prices in SSA: since good rainfall patterns support good harvests, this has a potential to reduce food prices due to bumper harvests. The findings further show that an increase in temperature leads to a rise in food prices, meaning areas in SSA experiencing climate shocks are more likely to experience a rise in food inflation. This indicates that much climate finance should be extended to areas in SSA with higher temperature shocks, compared to those with lesser temperature shocks. The rainfall results also show the need to prioritise investment policies that lead to reliable water supply, like irrigation and reinforcement of water storage facilities in all households.

Further, the results show that SSA countries where governments show greater readiness to mitigate and adapt to climate change are better able to reduce food prices compared to the other readiness variables (social and economic). This implies that SSA governments should brace their minds and activities to fight against climate change, as it will help attract more CF and increase food security, which will translate to lower food prices.

In summary, SSA countries receiving more CF, improving their fight against corruption, having a good rainfall pattern and reduced extreme temperatures, experiencing domestic currency depreciation, which have a larger population with high GDP growth, reduced food import and increased domestic food supply, and exhibit high governance and social readiness, will experience stable or reduced food prices. Based on these findings, it is recommended that donors increase the amount of CF extended to SSA, especially in climate-smart agriculture, to aid in achieving food security through lower food prices. Additionally, CF recipients, such as SSA, should strengthen their fight against corruption to reduce the leakage of CF and enhance food access. Finally, increased climate finance should be extended to areas in SSA currently experiencing temperature shocks such as the horn of Africa, South Africa and some parts of West Africa. Future studies could examine how CF is contributing to gender inequality in the food sector.

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Abstracts in Slovene

Vpliv kmetijske proizvodnje na gospodarsko rast v Zimbabveju

Simbarashe Mhaka in Raynold Runganga

Da bi dosegle vključujočo rast ter zmanjšanje revščine in neenakosti, bi morale afriške države okrepiti delovno intenzivno kmetijsko proizvodnjo, ki jim jo omogoča obilje naravnih virov in delovne sile. V pričujočem prispevku proučujemo vpliv kmetijstva na gospodarsko rast Zimbabveja, pri čemer uporabimo model avtoregresivno porazdeljenega zamika (ARDL) s podatki za obdobje od leta 1970 do 2019. Rezultati kažejo, da kmetijska proizvodnja kratkoročno pomembno pozitivno vpliva na gospodarsko rast, medtem ko dolgoročno nanjo ne vpliva. Poleg tega raziskava potrjuje, da imajo inflacija, državna poraba in bruto investicije v osnovna sredstva pozitiven vpliv na gospodarsko rast tako dolgokot kratkoročno. Čeprav ima kmetijski sektor pomembno vlogo na zgodnjih stopnjah gospodarskega razvoja, pa v Zimbabveju ne more vzdrževati trajnostne gospodarske rasti skozi daljše obdobje. Za spodbujanje kmetijske proizvodnje in trajnostne gospodarske rasti so potrebni dodatni vzvodi makroekonomske politike.

Ključne besede: kmetijska proizvodnja, gospodarska rast, model avtoregresivno porazdeljenega zamika (ARDL)
Klasifikacija JEL: Q1, O4, F43, C13
Managing Global Transitions 21 (4): 303–328

Kapitalska struktura, uspešnost podjetja in izpostavljenost tveganju: novi dokazi iz držav OECD

Tanzina Akhter, Sabrin Sultana in Abul Kalam Azad

Optimalna kapitalska struktura je ključno orodje za povečanje uspešnosti podjetja ob zmanjšanju tveganj. Na podlagi tega izhodišča preverimo, kako kapitalska struktura vpliva na uspešnost podjetja in izpostavljenost tveganjem. Uporabljamo močno uravnotežen panel 3.344 opazovanj podjetij-let v desetih različnih državah OECD za obdobje 2006–2016. Rezultati kažejo, da podjetja s kratkoročno zadolženostjo običajno izkazujejo visoko računovodsko uspešnost, vendar zmanjšano tržno uspešnost, medtem ko so podjetja z večjo dolgoročno in celotno zadolženostjo v veliki meri izpostavljena zmanjšani računovodski in tržni uspešnosti. Večja kot je dolgoročna celotna zadolženost, večje so možnosti, da bodo podjetja postala ranljiva v smislu plačilne nesposobnosti. Ugotovitve so robustne, kar kažejo alternativni kazalniki kapitalske strukture, uspešnosti podjetja in tveganja, alternativni model razvoja in dvostopenjska sistemska cenilka GMM za nadzor endogenosti. Ta raziskava bo pomembna za menedžerje podjetij in oblikovalce politik pri snovanju ustrezne kapitalske strukture za maksimiranje uspešnosti podjetja ob zmanjšanju tveganj v zvezi z zadolževanjem.

Ključne besede: kapitalska struktura, uspešnost, tveganje, Organizacija za gospodarsko sodelovanje in razvoj (OECD)
Klasifikacija JEL: G2, G3, M4
Managing Global Transitions 21 (4): 329–351

Poraba fosilne energije, emisije ogljikovega dioksida in stopnja umrljivosti odraslih v Nigeriji

Oluwasegun Olawale Benjamin, Gbenga Wilfred Akinola in Asaolu Adepoju Adeoba

Zdravstvene posledice porabe fosilne energije in emisij ogljikovega dioksida (CO_2) so globalna skrb. Pričujoča raziskava proučuje učinek porabe fosilne energije in emisij CO_2 na stopnjo umrljivosti odraslih v Nigeriji. Opira se na proizvodno funkcijo v zdravstvu in uporablja tehniko avtoregresivnega porazdeljenega zamika za analizo podatkov časovnih vrst od leta 1980 do 2019. Rezultati modela kažejo, da poraba fosilne energije kratkoročno zmanjša stopnjo umrljivosti odraslih, medtem ko emisije CO_2 kratkoročno in dolgoročno umrljivost povečajo. Poleg tega pri pojasnjevanju umrljivosti odraslih ugotovimo, da državna poraba v zvezi z zdravstvom sledi obrnjeni U-obliki, medtem ko ima povezava med neposrednimi tujimi naložbami in smrtnostjo odraslih v Nigeriji obliko črke U. Odprtost gospodarstva in denarna politika sta nepomembni tako kratko- kot dolgoročno. Priporočljivo je, da bi vlada za izboljšanje kakovosti življenja energijo fosilnih goriv nadomestila s čisto energijo, povečala davek na emisije CO_2 in da bi finančna sredstva za zdravstvo dejansko porabila za izboljšanje zdravstvenih storitev.

Ključne besede: stopnja umrljivosti odraslih, emisije CO_2, poraba fosilne energije, Nigerija
Klasifikacija JEL: I15, I18, I12
Managing Global Transitions 21 (4): 353–384

Ali podnebno financiranje pomaga stabilizirati cene hrane v podsaharski Afriki?

Isaac Doku in Andrew Phiri

Pričujoča raziskava proučuje potencialni vpliv podnebnega financiranja (PF) na cene hrane v podsaharski Afriki (PSA), saj podnebne spremembe povzročajo pomanjkanje hrane in povečevanje cen hrane. Raziskava analizira podatke iz 43 držav PSA med letoma 2006 in 2018 z uporabo modela panela s fiksnim učinkom z Driscoll-Kraayevimi standardnimi napakami in metodo momentov kvantilnih regresij (MMQR). Ugotovitve nakazujejo, da bodo države v PSA, ki prejemajo več PF, ki izboljšujejo svoj boj proti korupciji, imajo zadostno količino padavin, nimajo prevelikih temperaturnih ekstremov, imajo depreciirane valute, večje število prebivalcev in višjo rast BDP, ki zmanjšujejo uvoz hrane in povečujejo domačo preskrbo s hrano ter izkazujejo visoko upravljavsko in družbeno pripravljenost, verjetno stabilizirale ali znižale cene hrane. Glede na te rezultate priporočamo, da vlade PSA namenijo prednost boju proti korupciji, da bi pridobile zaupanje donatorjev in povečale PF, kar bi pripeljalo do zmanjšanja cen hrane v podregiji. Nadalje ugotovitve kažejo, da dobri vzorci padavin zmanjšujejo cene hrane: to kaže na potrebo držav PSA za vlaganje v politike, ki vodijo k zanesljivi oskrbi z vodo, kot je namakanje.

Ključne besede: podnebno financiranje, cene hrane, podnebne spremembe, podsaharska Afrika
Klasifikacija JEL: C23, C32, C51, Q54.
Managing Global Transitions 21 (4): 385–414