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.

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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

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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

$$\begin{aligned}\mathrm{FP}_{it} &= \beta_1 + \beta_2\mathrm{CF}_{it} + \beta_3\mathrm{COC}_{it} + \beta_4 \mathit{Rainfall}_{it} + \beta_5 \mathit{Temperature}_{it} \\ &\quad + \mu_t + e_{it}, \end{aligned} \tag{1}$$

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.

$$\begin{aligned}\mathrm{FP}_{it} &= \beta_1 + \beta_2\mathrm{CF}_{it} + \beta_3\mathrm{COC}_{it} + \beta_4 \mathit{Rainfall}_{it} + \beta_5 \mathit{Temperature}_{it} \\ &\quad + \beta_6 \mathit{Forex}_{it} + 7\mathit{Population}_{it} + 8\mathrm{GDP}\mathit{growth}_{it} \\ &\quad + \beta_9 \mathit{Trade}_{it} + \mu_t + e_{it}. \end{aligned} \tag{2}$$

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.

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

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 (autocorrelation): 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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