The Journal of Economic Asymmetries 32 (2025) e00438

Contents lists available at ScienceDirect

The Journal of Economic Asymmetries

journal homepage: www.elsevier.com/locate/jeca

Causal links between public debt and inflation in sub-Saharan African countries

Akingbade U. Aimola *, Nara Monkam

Department of Economics, University of Pretoria, Private bag X20, Hatfield, 0028, Pretoria, South Africa

ARTICLE INFO

JEL classification:
C33
E31
E52
E62
H63

Keywords:
Public debt
Inflation
Panel symmetry/asymmetry causality
Revenue mobilisation

ABSTRACT

This study aims to investigate and compare both symmetric and asymmetric causal relationships between public debt and inflation across a panel of 14 sub-Saharan African countries over the period 1990 to 2021. It also examines trends in Country Policy and Institutional Assessment (CPIA) scores, particularly in the domains of debt policy and the efficiency of revenue mobilization. The analysis employs Konya's (2006) symmetric bootstrap panel causality test and an asymmetric approach developed by Yılancı and Aydın (2017), which builds on Granger and Yoon (2002) and Konya's methodology. The results reveal notable nonlinearity and considerable cross-country variation. Under the symmetric specification, causality from public debt to inflation is found in only four countries. However, when asymmetry is incorporated, this number increases to twelve. Similarly, while causality from inflation to debt is observed in four countries using the symmetric model, the asymmetric framework reveals evidence in eleven countries. These findings contribute to literature by offering a comparative perspective on the debt-inflation nexus. Moreover, the results indicate the presence of cross-sectional dependence across the panel and confirm country-specific heterogeneity. The analysis of CPIA indicators also points to varied levels of institutional capacity in public debt management and revenue mobilization across the region. Notably, Kenya's top performance in revenue mobilisation suggests that robust institutional frameworks can enhance the predictive relationship between increase public debt levels and inflation. The study's findings carry significant implications for fiscal and monetary policy in sub-Saharan Africa.

> *"A national debt if it is not excessive will be to us a national blessing; it will be powerful cement of our union. It will also create a necessity for keeping up taxation to a degree which without being oppressive will be a spur to industry."*
>
> (Hamilton, 1781)

1. Introduction

Macroeconomic stability is intrinsically linked to the relationship between public debt and inflation, a relationship that gained increased attention in the aftermath of the COVID-19 pandemic. This concern is especially pertinent in sub-Saharan Africa (SSA), where ensuring fiscal sustainability remains a pressing policy challenge. In recent years, many countries in the region have

* Corresponding author.
E-mail addresses: akingbade.aimola@up.ac.za, auaimola@gmail.com (A.U. Aimola), fn.monkam@up.ac.za (N. Monkam).

https://doi.org/10.1016/j.jeca.2025.e00438
Received 16 February 2025; Received in revised form 2 August 2025; Accepted 15 September 2025
Available online 25 September 2025

increasingly turned to public borrowing both domestic and external to finance infrastructure projects and social programmes. According to Nguyen (2015a) most developing countries, including those in this region rely on public debt to bridge budget gaps and stimulate economic growth. Since debt relief gains under the Heavily Indebted Poor Countries (HIPC) initiative, public debt levels have steadily risen, driven by adverse commodity price shocks, expansionary fiscal policies, and pandemic-induced expenditures. These trends has raise concerns about potential macroeconomic instability, progress toward achieving the Sustainable Development Goals (SDGs), African Union's Agenda 2063, and similar regional development programs.

A deeper understanding of how public debt influences inflation is essential for designing effective and well-coordinated fiscal and monetary policy responses (International Monetary Fund (IMF), 2023a, 2023b). The acceleration in inflation across SSA has brought renewed attention to its fiscal roots, particularly the expanding role of public debt. While borrowing is often necessary to fund development, excessive debt accumulation can compromise price stability and weaken overall economic performance. This raises critical questions about the structure of the link between public debt and inflation, whether it operates symmetrically or asymmetrically, and how it varies based on country-specific fiscal frameworks, monetary policy settings, debt management capacities, institutional capacities for revenue mobilization, and if the wealth effect of public debt is muted or less prominent. This analysis is especially relevant in the current context, as countries in the region grapple with post-pandemic recovery challenges, climate-related fiscal pressures, and rising global interest rates. In addition, since causality testing provides a clearer understanding of the relationship between these variables, this analysis is particularly important in the sub-region, where public debt ratios have been on the raise following recent debt relief efforts that had substantially lowered them in many countries in the sub-region.

In heavily indebted SSA economies, traditional tools like raising interest rates to combat inflation may produce counterproductive outcomes. Prior research (Blanchard, 2004; Favero & Giavazzi, 2004) shows that such measures can elevate the cost of servicing debt, increase the risk of default, and amplify market volatility. These dynamics may, in turn, elevate inflation expectations and destabilize exchange rates. Therefore, a more holistic strategy incorporating sound public debt management, improved domestic revenue collection, and coordinated fiscal and monetary policies is crucial to safeguarding macroeconomic stability in the region.

From a theoretical perspective, the Fiscal Theory of Price Level (FTPL) underscores the central role of public debt in influencing price levels, suggesting that inflation can arise from fiscal imbalances even when monetary policy remains passive (Cochrane, 2000; Sargent & Wallace, 1981; Woodford, 1995). In many SSA countries, weak tax administration and fiscal inefficiencies make these dynamics particularly relevant. A majority of SSA countries operate under a non-Ricardian framework due to inefficient tax and spending policies, making fiscal strength crucial for economic stability (Fanizza & Soderling, 2006). Moreover, given institutional differences and varying levels of economic resilience, debt-inflation relationship is unlikely to be linear or homogeneous across the region. As such, relying solely on linear models may obscure important variations and lead to potentially misleading conclusions.

To address these complexities, and given the importance of capturing nonlinear dynamics in time series analysis, Aimola and Odhiambo (2022a) demonstrate that total public debt and inflation may exhibit nonlinear behavior. This supports the use of nonlinear modeling techniques to analyze their relationship. Accordingly, this study applies nonlinear Granger causality methods alongside symmetric analysis. A panel data causality framework is employed, allowing for both symmetric and asymmetric assessments of causal link between these variables. Using methodologies developed by Konya (2006), and Yılancı and Aydın (2017), the analysis accommodates country-specific causality, cross-sectional interdependencies, and asymmetry, factors often neglected in earlier research. Hatemi-J's econometric method is applied to decompose changes in public debt and inflation, enabling the distinction between increases (positive shocks) and reductions (negative shocks), thereby offering a more intricate understanding of causal links between public debt and inflation. Konya (2006) and Yılancı and Aydın (2017) estimation strategies do not impose theoretical constraints on relationship between variables, allowing for our empirical assessment of causality should wealth effect of public debt be less prominent or muted in the region. Recent studies have argued that the wealth effect of public debt may be less prominent or conditional in SSA economies due to the credibility of fiscal and monetary authorities, the degree of financial market development, the nature of fiscal–monetary interactions, and the overall quality of institutions (Aimola & Odhiambo, 2021, 2022a, 2022b; Hooley et al., 2024; Reinhart & Rogoff, 2010). To the best of our knowledge, this is the first study to apply these techniques to an empirical causality analysis between public debt and inflation, offering critical insights that may assist SSA countries in pursuing sustainable debt levels and low inflation through strategic debt, inflation, and revenue management. It also opens up important empirical questions regarding the wealth effect of public debt in developing economies, especially in SSA, which warrant further investigation.

This research provides empirical evidence on debt-inflation predictive relationship in 14 SSA countries between 1990 and 2021, using panel causality tests. The findings reveal significant nonlinearity and substantial variation across countries. Under the symmetric model, causality from public debt to inflation is observed in just four countries. However, when asymmetry is accounted for, this number increases to twelve. Likewise, causality from inflation to debt is detected in four countries under a symmetric framework but rises to eleven under an asymmetric analysis. These outcomes highlight the importance of accounting for nonlinear dynamics in policy design.

Overall, this paper provide insights into predictive relationship between public debt and inflation in SSA. It underscores the need for tailored, evidence-based policy interventions to achieve sustainable debt paths without undermining price stability. Furthermore, it lays the groundwork for future research by advocating for a less prominent or conditional wealth effect of public debt in the region, and a disaggregated analysis of total public debt into external and domestic components, to better understand their predictive impacts on inflation dynamics across countries in the region. Although experiences in SSA complicates theoretical landscape of the wealth effects of public debt. We acknowledge its theoretical relevance and recognize that its empirical significance may become more apparent as financial and institutional development progresses. This consideration is particularly pertinent, given the ongoing debate among scholars and policymakers regarding the extent to which public debt drives inflation in SSA economies. Future studies may consider introducing intermediary variables, such as money supply, interest rate, exchange rate, or economic growth, within a multivariate

causality framework to assess whether the inclusion of these factors activates the wealth effect channel and yields results that differ significantly from those reported in this study.

The rest of the paper is organized as follows: Section 2 outlines recent trends in public debt and inflation and examines CPIA ratings related to debt management and revenue performance; Section 3 brief related theoretical and empirical literature review; Section 4 outlines the estimation techniques; Section 5 presents study results; and Section 6 ends the paper with conclusions and policy recommendations.

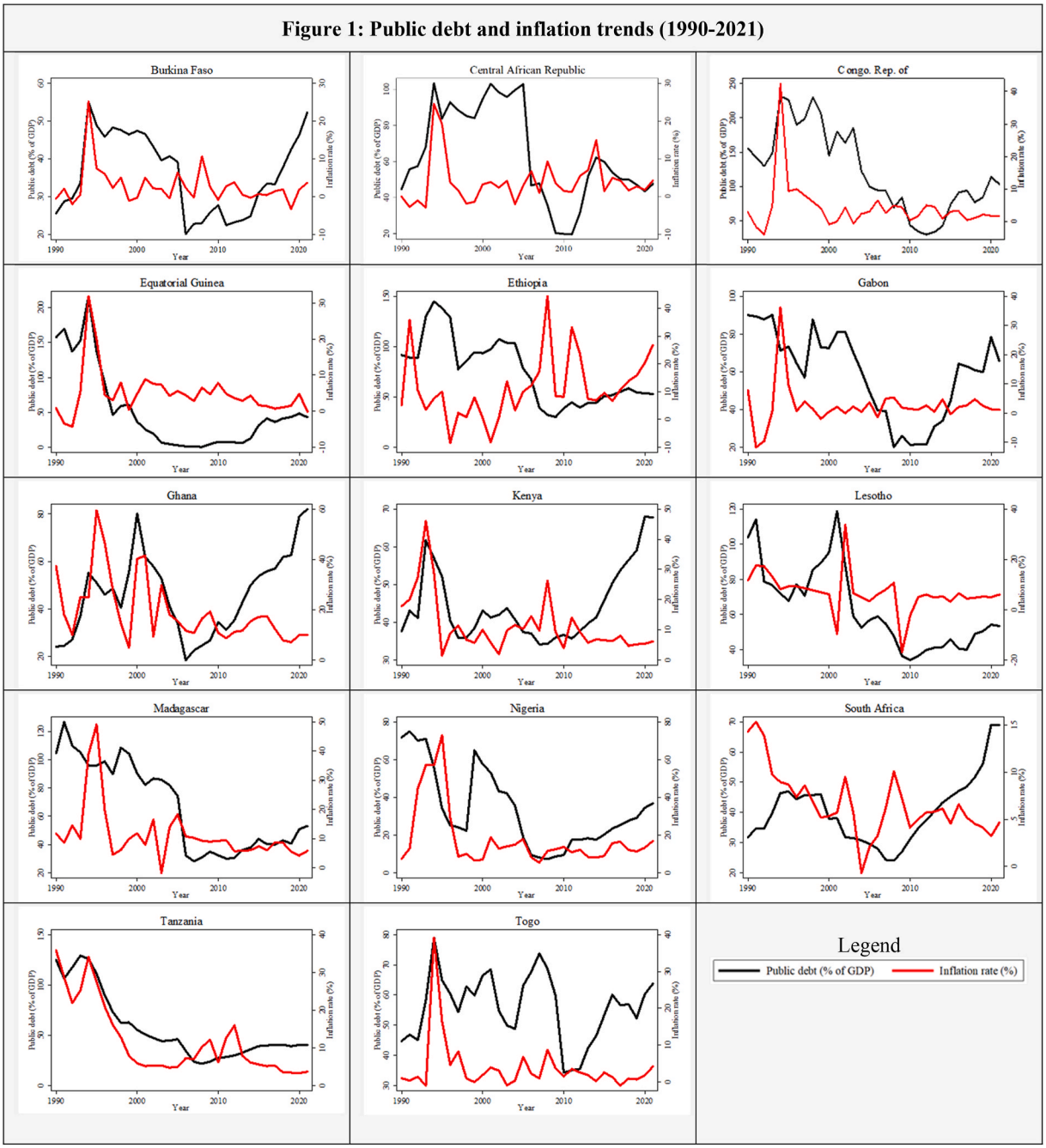

Fig. 1. Public debt and inflation trends (1990–2021) across selected sub-Saharan African Countries.
Source: Authors' compilation using STATA, based on data from World Bank (2023) and International Monetary Fund (IMF) (2023c).

2. Trends in public debt, inflation, debt policy and revenue mobilisation efficiency

2.1. Public debt and inflation dynamics (1990–2021)

Fig. 1 presents historical evolution of public debt-to-GDP ratios and inflation rates for 14 sub-Saharan African countries between 1990 and 2021. A notable pattern emerges in the early 2000s, where several countries particularly Congo, Ghana, Nigeria, and Tanzania experienced a sharp drop in public debt levels. This decline coincides with external public debt relief provided through the Heavily Indebted Poor Countries (HIPC) Initiative. However, this downward trend was not sustained as debt levels began to rise again after 2010. This resurgence is primarily attributed to increased government spending on infrastructure and social programs, adverse commodity price movements, and fiscal strains arising from the COVID-19 pandemic, with countries like Ethiopia, Ghana, Kenya, and South Africa especially affected. In the majority of cases, countries reported total public debt-to-GDP ratios that remained slightly under the 70 % sustainability benchmark set by the IMF and World Bank for sub-Saharan Africa. Although visual trends show that public debt ratios generally exceeded inflation rates, higher debt levels did not lead to corresponding increases in inflation. In fact, inflation remained relatively subdued in most countries during this period, suggesting enhanced monetary policy credibility. Inflation was more volatile and elevated in the 1990s, but it gradually declined, with most countries attaining single-digit inflation rates by the 2010s.

A close examination of Fig. 1 indicates a weak contemporaneous relationship between public debt and inflation among countries in the sample. The figure does not provide clear evidence of a consistent positive or negative correlation between the two variables. Their movements vary across different sub-periods, with public debt and inflation sometimes increasing together and at other times moving in opposite directions. Despite fluctuations in public debt, inflation was generally well-managed. In many instances, the stabilization of inflation occurred before or independently of any significant reduction in public debt, suggesting that monetary policy reforms may have played a more prominent role than fiscal adjustments in managing inflation expectations. Given these dynamics, the visual trends analysis provides only a limited insight into public debt-inflation relationship in the study countries. To complement this, it is essential to conduct an empirical analysis using an econometric approach capable of capturing intricate causal links and distinguishing between the effects of positive and negative changes in public debt on inflation, and vice versa.

2.2. Trends in CPIA debt policy and revenue mobilisation efficiency ratings (2005–2022)

The macroeconomic relationship between public debt and tax revenue has long been a subject of debate, dating back to Alexander Hamilton's writings in 1781. Contemporary literature suggests that moderate levels of public borrowing, and the efficiency of public investment can help smooth tax burdens without impeding economic growth, an important consideration for SSA economies (Coulibaly et al., 2019; Elmendorf & Mankiw, 1999; Presbitero, 2016). In these countries, tax revenues are a critical source for financing development priorities and managing fiscal deficits. However, many governments in the region face structural challenges in expanding and diversifying their revenue bases. With public expenditure increasing more rapidly than revenue, many SSA countries have become increasingly reliant on borrowing, highlighting the urgency of improving domestic resource mobilization frameworks.

These fiscal challenges underscore the relevance of the fiscal theory of inflation in developing economies, where limited tax capacity increases the risk of inflationary financing. In this context, understanding the institutional underpinnings of fiscal performance becomes essential. The World Bank's Country Policy and Institutional Assessment (CPIA) provides useful diagnostics through two key indicators: the debt policy score, which evaluates a country's ability to manage public debt sustainably and mitigate fiscal risks, and the revenue mobilisation efficiency score, which assesses the effectiveness of tax policy and administration in generating government revenue.

CPIA scores range from 1 (low) to 6 (high) and are used to classify countries as strong, medium, or weak performers in fiscal policy domains. As of 2022, as indicated in Tables 1 and 2, countries such as the Central African Republic, Republic of Congo, Ethiopia, and Ghana were rated weak in debt policy, reflecting significant vulnerabilities related to debt sustainability and servicing. In contrast, Burkina Faso, Kenya, Madagascar, Nigeria, and Tanzania were assessed as strong performers in debt management. On revenue mobilization front, weak scores were recorded in the Central African Republic, Republic of Congo, Nigeria, and Tanzania, while Burkina Faso, Ethiopia, Ghana, Madagascar, and Togo were rated medium. Kenya and Lesotho stood out with relatively high scores in revenue efficiency, with Kenya achieving a balanced score of 4 in both indicators signaling sound fiscal governance with room for enhancement.

Table 1
Country policy and institutions assessment - debt policy.

Debt policy threshold	Period	Countries
Weak policy (CPIA $\leq$3)	2022	Central African Republic, Congo Rep., Ethiopia, Ghana.
	Average (2005–2021)	Central African Republic, Congo Rep., Togo.
Medium policy (3 < CPIA <4)	2022	Lesotho, Togo.
	Average (2005–2021)	Ethiopia, Ghana, Lesotho.
Strong policy (CPIA $\geq$4)	2022	Burkina Faso, Kenya, Madagascar, Nigeria, Tanzania.
	Average (2005–2021)	Burkina Faso, Kenya, Madagascar, Nigeria, Tanzania.

Note: Data not available for Equatorial Guinea, Gabon and South Africa.
Source: Authors' calculation based on data from World Bank (2023).

Table 2
Country policy and institutions assessment - efficiency of revenue mobilization.

Efficiency of revenue mobilization policy threshold	Period	Countries
Weak policy (CPIA ≤3)	2022	Central African Republic, Congo, Rep., Nigeria, Tanzania.
	Average (2005–2021)	Central African Republic, Congo, Rep., Nigeria, Togo.
Medium policy (3 < CPIA <4)	2022	Burkina Faso, Ethiopia, Ghana, Madagascar, Togo.
	Average (2005–2021)	Burkina Faso, Ethiopia, Ghana, Madagascar, Tanzania.
Strong policy (CPIA ≥4)	2022	Kenya, Lesotho.
	Average (2005–2021)	Kenya, Lesotho.

Note: data not available for Equatorial Guinea, Gabon and South Africa.
Source: Authors' calculation based on data from World Bank (2023).

Fig. 2 presents annual CPIA scores for debt policy and revenue mobilization efficiency across twelve SSA countries from 2005 to 2022. The data indicate that most countries consistently fall within the moderate range of 3 to 4 in both indicators, pointing to substantial scope for institutional and policy improvement. Togo and the Central African Republic showed notable gains over time, suggesting the positive impact of recent fiscal reforms. In contrast, Ethiopia and Ghana experienced declining debt policy scores, likely due to increased debt stress and shrinking fiscal space. In addition, countries such as Republic of Congo, Kenya, Lesotho, and Nigeria exhibited relatively stagnant revenue mobilization scores, reflecting enduring structural constraints in tax administration.

Kenya's comparatively strong performance reinforces the value of institutional strength in promoting fiscal sustainability and highlights the importance of econometric analysis to understand the dynamics between public debt and inflation. Although CPIA data are unavailable for Equatorial Guinea, Gabon, and South Africa, investigating debt-inflation linkages in these countries remains valuable for capturing regional variation.

Overall, the analysis highlights significant differences in institutional capacity to manage public debt, control inflation, and enhance revenue mobilization across the countries examined. According to Montiel (2005), maintaining a sustainable and well-structured public debt portfolio requires governments to manage inflation effectively and shield their budgets from macroeconomic shocks. As a result, the optimal composition of public debt varies depending on a country's specific economic conditions. Accordingly, this study employs an estimation approach capable of capturing country-specific dynamics, which is essential for understanding the heterogeneous relationship between public debt and inflation within the panel.

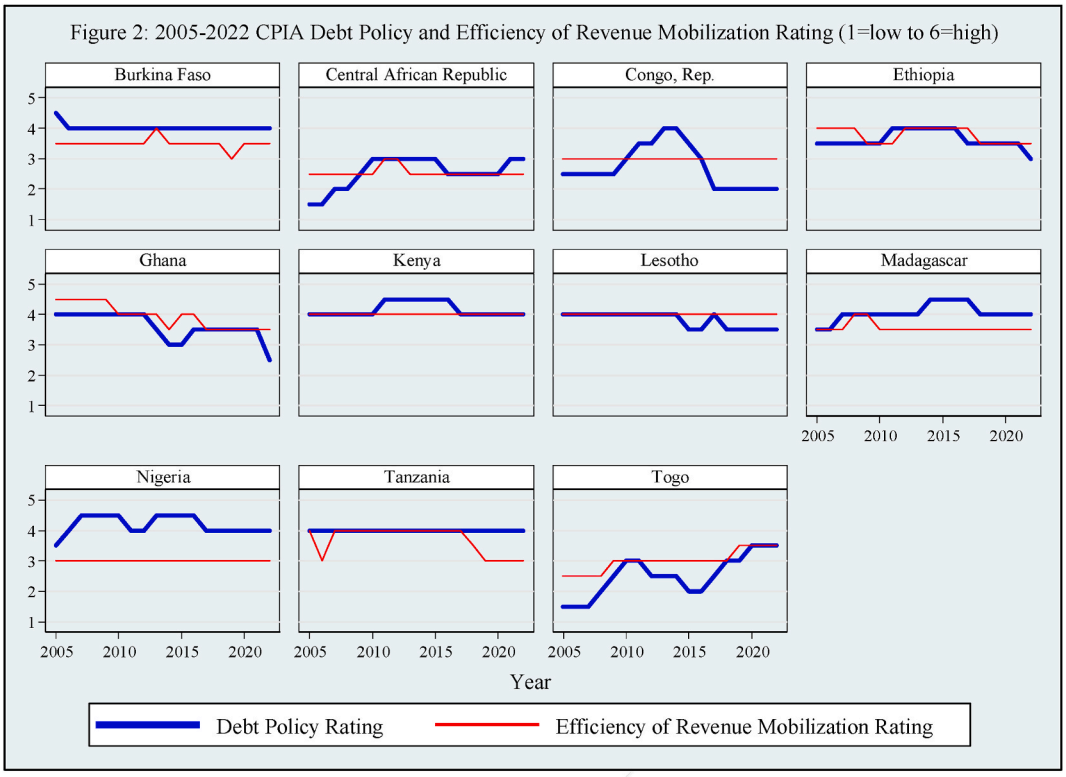

Fig. 2. Trends in CPIA debt policy and revenue mobilization ratings for selected sub-Saharan African countries (2005–2022).
Source: Authors' compilation using STATA based on data from World Bank (2023).

3. Brief related theoretical and empirical literature review

The macroeconomic fallout of the COVID-19 pandemic has seen a decline in government revenue accumulation and a sharp rise in public debt across sub-Saharan Africa. A debate has emerged over whether this rise is driven by insufficient tax revenue for budget deficits or as a strategy for "cheap" growth funding from the East. Policymakers are now questioning the long-term sustainability of these funding approaches, recognizing that sound debt management requires an understanding of fiscal impacts on monetary policy, inflation dynamics, and economic stability.

Inflation has long been a subject of debate across several theoretical perspectives. The classical monetarist view championed by Friedman (1968) posits that inflation is "always and everywhere a monetary phenomenon." Within this framework, inflation results from excessive growth in money supply. In the short run, expansionary monetary policy can raise both output and prices, but in the long run, it only affects the price level. This view aligns with the Ricardian framework where monetary policy is active, fiscal policy is passive, and government debt is not considered net wealth (Barro, 1974, 1989). Under Ricardian Equivalence, price levels are primarily driven by changes in the money supply (Attiya et al., 2008), and fiscal adjustments respond to monetary conditions to ensure inter-temporal budget constraints are met (Davig & Leeper, 2007, 2011; Leeper, 1991).

Contrary to this, the Fiscal Theory of Price Level emerges from a non-Ricardian perspective, where fiscal policy can actively influence price level independently of money supply changes (Cochrane, 1999, 2005; Woodford, 1995, 1998). FTPL posits that government debt has a wealth effect, increased public debt raises household wealth and aggregate demand, thereby exerting upward pressure on prices (Kwon et al., 2006). In this framework, the inter-temporal government budget constraint replaces money supply as the anchor of price stability (Leeper, 1991; Sims, 1994; Woodford, 1995). When fiscal policy is active and monetary policy passive, prices adjust to ensure that the real value of outstanding nominal debt equals the present value of future primary surpluses (Afonso, 2002). FTPL therefore offers an alternative mechanism for price level determination, especially in contexts where fiscal dominance prevails.

This theoretical shift has important implications for developing countries, where governments often issue domestic debt but lack the fiscal capacity to raise adequate tax revenues (Beck-Friis & Willems, 2017). In such economies, monetary policy tends to be passive, and fiscal authorities play a dominant role in influencing inflation. Studies have shown that anti-inflationary monetary policies alone may not ensure price stability in these contexts (Attiya et al., 2008; Christiano & Fitzgerald, 2000; Loyo, 1999).

Blanchard (2004) and Favero and Giavazzi (2004) argue that in high-debt economies, increasing interest rates to control inflation can inadvertently raise debt servicing costs, elevate default risks, and lead to capital flight and exchange rate depreciation, all of which reinforce inflationary pressures. Thus, FTPL underscores the importance of fiscal discipline in inflation management, especially in developing countries with large public debts. It challenges the traditional view that only monetary aggregates determine inflation, calling for coordinated fiscal and monetary policy to ensure macroeconomic stability. As Cochrane (2001) and Sims (2013) argue, controlling inflation in highly indebted economies requires accounting for the sustainability and credibility of fiscal policy alongside monetary interventions.

Recent literature has increasingly acknowledged that inflation is not solely a monetary issue but also a fiscal one (Catao & Terrones, 2005; Kwon et al., 2006; Lai et al., 2015; Nastansky & Strohe, 2015; Urquhart, 2021; Aimola & Odhiambo, 2021, 2022a, 2022b; Dumitrescu et al., 2022). The FTPL highlights the role of government debt as a channel through which fiscal policy can affect inflation, especially through wealth effects. This view also emphasizes the need for policy coordination where both fiscal and monetary authorities jointly influence macroeconomic outcomes (Sargent & Wallace, 1981; Woodford, 1994). Fanizza and Soderling (2006) further argue that macroeconomic stability requires a sound fiscal position beyond just monetary policy adjustments. Moreover, theories like the crowding-out effect suggest that increased government borrowing raises interest rates, reduces private investment, and tightens supply-side constraints, contributing to inflationary pressures (Buiter, 1977; Carlson & Spencer, 1975; Spencer & Yohe, 1970; Tanzi & Fanizza, 1995). Similarly, the Olivera-Tanzi effect highlights a feedback loop in which inflation reduces the real value of tax revenues, exacerbating fiscal deficits and reinforcing inflation (Tanzi, 1991).

Empirical studies on public debt-inflation nexus have produced mixed findings. Some, including Cardoso and Fishlow (1990), Wijnbergen and Budina (2001), Kwon et al. (2006), Bildiric and Ersin (2007), Adnan et al. (2008), Karakaplan (2009), Ahmad et al. (2012), Khumalo (2013), Sims (2014), Lopes da Veiga et al. (2016), Nastansky and Strohe (2015), Nguyen (2015b), Romero and Marin (2017), Afonso and Ibraimo (2018), Maitra (2019), Urquhart (2021), Siddiqui et al. (2022), Sumba et al. (2024), and Buthelezi (2024) report a positive relationship, while others like (Bleaney, 1996; Essien et al., 2016; Maitra & Hossain, 2024; Wheeler, 1999) suggest a negative or weak link. A common limitation of these studies is the assumption of symmetry in public debt -inflation relationship, overlooking potential nonlinearities due to factors like economic crises, and regime shifts.

Contemporary research has begun exploring asymmetric dynamics. Reinhart and Rogoff (2010) hint at possible threshold effects, while studies by Aimola and Odhiambo (2022a), Dumitrescu et al. (2022), Olaoye et al. (2024), and Sharaf et al. (2024) explicitly test for asymmetric effects. However, such research remains limited, particularly for sub-Saharan African countries.

In terms of causality, existing studies (Aimola & Odhiambo, 2022b; Devapriya & Ichihashi, 2012; Essien et al., 2016; Ezirim et al., 2016; Lai et al., 2015; Odior & Arinze, 2017; Taghavi, 2000; Wleklińska, 2023; Yien et al., 2017) rarely examine nonlinear causality, especially within the African context. This study addresses this gap by investigating both symmetric and asymmetric causality between public debt and inflation in SSA. By employing econometric methods, it aims to uncover hidden causal relationships, offering critical insights for macroeconomic management, particularly amid revenue mobilization challenges and regional development agendas.

Theoretical and empirical evidence indicates that the relationship between public debt and inflation is complex and context-specific. While the monetarist perspective remains relevant, particularly in low-debt and inflation-targeting regimes, the FTPL offers a more nuanced framework for understanding inflation dynamics in highly indebted and fiscally constrained economies. This

highlights the importance of coordinated fiscal and monetary policies for effective inflation management and the preservation of macroeconomic stability in the region. Furthermore, based on the literature reviewed for this study, the preferred and conceptually consistent indicators are the annual growth rate of the Consumer Price Index (CPI) to measure inflation and the ratio of total public debt to nominal Gross Domestic Product (GDP) to measure public debt, as these would effectively capture the relationship between the two variables.

3.1. Research gap

A review of existing literature indicates that although significant strides have been made in examining the influence of public debt on inflation dynamics, additional research is necessary to fully understand the complex and context-specific effects, particularly through the application of models that better reflect these complexities. Many prior studies assume a symmetric relationship between public debt and inflation. However, emerging evidence points to an asymmetric pattern in public debt behavior, often driven by various economic shocks. Aimola and Odhiambo (2022a) demonstrate that total public debt and inflation may exhibit nonlinear behavior, supporting the use of nonlinear modeling techniques to analyze their relationship. Additionally, findings by Olaoye et al. (2024) reveal that inflation may respond differently to positive versus negative fiscal shocks, both in direction and magnitude. This suggests that applying symmetric models in such contexts may be overly simplistic and potentially misrepresent the underlying economic dynamics.

Given these gaps, there is a growing need for research to employ innovative methodologies to investigate public debt-inflation nexus, especially in the context of SSA and other developing regions. Addressing this need, the present study adopts Konya's (2006) symmetric bootstrap panel causality approach, alongside an asymmetric extension by Yılancı and Aydın (2017), to explore the causality between public debt and inflation more comprehensively. This approaches do not impose theory-based restrictions on relationship between variables, allowing for our empirical assessment of causality should wealth effect of public debt be less prominent or muted in the region. Recent studies have argued that the wealth effect of public debt may be less prominent or conditional in SSA economies due to the credibility of fiscal and monetary authorities, the degree of financial market development, the nature of fiscal–monetary interactions, and the overall quality of institutions (Aimola & Odhiambo, 2021, 2022a, 2022b; Hooley et al., 2024; Reinhart & Rogoff, 2010). By considering a less prominent or muted wealth effect and using a bivariate causality model, we recognize its theoretical importance, and acknowledge that its empirical relevance may become more pronounced as financial and institutional development advances. This consideration is particularly relevant as the extent to which public debt affects inflation in domestic SSA economies remains a subject of active debate among scholars and policymakers amid issues of concessional debt levels and "true" market rate of domestic public debt.

4. Data and methodology

4.1. Variable measurement and justification

This study employs two primary macroeconomic indicators to examine the relationship between public debt and inflation: the annual growth rate of the CPI as a proxy for inflation, and the ratio of total public debt to nominal GDP as a proxy for public debt. These indicators are widely recognized in empirical research as appropriate measures for capturing inflationary trends and the fiscal burden of public debt (Aimola and Odhiambo, 2021, 2022a, 2022b; Dumitrescu et al., 2022; Kwon et al., 2006; Lai et al., 2015; Maitra, 2019; Nastansky & Strohe, 2015; Urquhart, 2021).

Public debt-to-GDP ratio remains one of the most commonly used indicators for evaluating a country's fiscal sustainability and macroeconomic resilience. It reflects the size of a government's debt relative to the economy's overall output and is considered a critical measure of the government's capacity to service its debt without compromising macroeconomic stability (IMF, 2021). While a high ratio may indicate fiscal stress, reduced fiscal space, and increased borrowing costs due to default risk, a low ratio is typically associated with greater fiscal flexibility and a more stable economic outlook. According to Reinhart and Rogoff (2010), excessive public debt can constrain a government's ability to respond effectively to economic downturns. Elevated debt levels may reduce the fiscal space needed for counter-cyclical policies such as stimulus spending or public investment during crises. When a significant portion of government revenue is allocated to debt servicing, critical investments in infrastructure, education, and health may be deferred, undermining long-term growth prospects. Conversely, countries with moderate debt burdens tend to have more room to maneuver during periods of economic volatility, facilitating quicker recovery. However, a low debt ratio does not automatically imply fiscal sustainability if the government lacks the institutional and revenue-generating capacity to maintain primary surpluses and meet debt service obligations efficiently.

In constructing the empirical model, both theoretical insights and prior empirical evidence were considered to guide the selection of these variables. The FTPL which is rooted in non-Ricardian frameworks emphasizes the role of fiscal variables, particularly public debt, in determining price level, especially in developing countries where fiscal dominance tends to be more pronounced. This contrasts with monetarist perspectives, which highlight monetary aggregates as the primary drivers of inflation. Furthermore, since fiscal deficits in many of the countries studied are largely financed through government borrowing or money creation, we also draw on the Oliver-Tanzi argument, which posits a bidirectional causality between public finance and inflation, particularly in developing countries with weak tax systems. Based on this theoretical foundation, the growth rate of the CPI and the public debt-to-GDP ratio are considered appropriate and conceptually consistent proxies for measuring inflation and public debt, respectively.

4.2. Data

This study examines the causal link between public debt and inflation in a panel of 14 countries in sub-Saharan Africa over the period 1990 to 2021 using annual data. The choice of the countries and time period was influenced by the availability of reliable data for the variables. The countries sampled are Burkina Faso, Central African Republic, Equatorial Guinea, Ethiopia, Gabon, Ghana, Kenya, Lesotho, Madagascar, Nigeria, Republic of the Congo, South Africa, Tanzania and Togo. The variables used in this study are gross public debt (*PD*) and inflation (*INF*). Gross public debt data are sourced from the International Monetary Fund's database (International Monetary Fund (IMF), 2023c) and inflation rate from the World Bank's World Development Indicators (WDI) database (World Bank, 2023). Table 3 provide further detail on how each variable are measured.

4.3. Cross sectional dependence and slope homogeneity tests

Before implementing panel causality test, cross-section dependence and slope homogenous test are important in determining the choice of an efficient panel causality approach. Since shock in one country may affect other countries through international trade, financial integration and high degree level of globalization, cross-sectional dependence test reveal similarities and differences among the countries in the panel. According to Pesaran (2006) controlling for cross-sectional dependence in the panel prevents biased estimates. Therefore, in this study, the test proposed by Breusch and Pagan (1980) (LM_{BP}) and Pesaran (2004) (CD_{LM} and CD) for cross-sectional dependency among countries would be used under the null hypothesis of no cross-sectional dependence. The Lagrange Multiplier (LM) test of Breusch and Pagan (1980) is based on the average of the squared pair-wise correlation of the residuals of fitted model estimated by ordinary least squares regression. The LM test statistics is given by:

$$LM_{BP} = T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\widehat{\rho}_{ij}^{2} \rightarrow \chi^{2}\frac{N(N-1)}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \tag{1}$$

Even though the Breusch and Pagan (1980) LM test is robust for heterogeneous panels and when the time dimension (T) is greater than the cross-section dimension (N), Pesaran (2004) highlighted drawback for when N→ ∞ by proposing the scaled version of the Breusch and Pagan (1980) LM test that can be considered for testing cross-sectional dependence when N→ ∞. The Pesaran (2004) scaled LM test statistics is calculated as follows:

$$CD_{LM} = \sqrt{\frac{1}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\left(T\widehat{\rho}_{ij}^{2}-1\right)\rightarrow \mathrm{N}(0,1) \ldots\ldots\ldots\ldots\ldots\ldots \tag{2}$$

According to Pesaran (2004) the test may likely exhibit substantial size distortions when N is large relative to T. To overcome this shortcoming with the Pesaran (2004) scaled LM test, a simple alternative which is based on the pair-wise correlation coefficients rather than their squares used in LM test was proposed by Pesaran (2004). This test is suitable for N→ ∞ and T→ ∞ in any order. The test statistics given by:

$$CD = \sqrt{\frac{2T}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\widehat{\rho}_{ij} \rightarrow N(0,1) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \tag{3}$$

Pesaran et al. (2008) propose a bias-adjusted LM test (LM_{adj}) as an alternative to the CD test, which can yield inconsistent results. The CD test may have limited effectiveness when the population average pair-wise correlations is zero, but the underlying individual population pair-wise correlations are non-zero. The bias-adjusted LM test represents a modification of the LM test. This test relies on the following statistical measure:

$$LM_{adj} = \sqrt{\frac{2}{N(N-1)}}\Sigma_{i=1}^{N-1}\Sigma_{j=i+1}^{N}\frac{(T-K)\widehat{\rho}_{ij}^{2}-\mu_{Tij}}{v_{Tij}^{2}} \rightarrow N(0,1) \quad \ldots\ldots\ldots\ldots \tag{4}$$

Testing for the presence of cross-country heterogeneity is key for bootstrap panel causality approach. Homogeneity test reveal structural differences of the series because countries may differ in their stages of development. Hence, the test help avoid masking country specific characteristics in the panel. The test proposed by Pesaran and Yamagata (2008) (Δ) and (Δ_{adj}) and Blomquist and Westerlund (2013) (Δ_{HAC}) and $\left(\Delta_{HAC_{adj}}\right)$ would be used in this study under the null hypothesis of slope homogeneity among countries. Blomquist and Westerlund (2013) test is more recent and would be used mainly for robustness checks. Pesaran and Yamagata (2008) improved on the early work of Swamy's (1970) slope homogenetity test making use of a standardized version of Swamy statistics and a

Table 3
Data sources and measurement of variables.

Variable	Description	Measurement	Source
INF	Inflation	Consumer price index (annual %)	World Bank (2023)
PD	Public Debt	Gross public debt (% of GDP)	International Monetary Fund (IMF) (2023c)

Source: Authors' compilation

bias modified version of the statistics to form two delta test statistics (Δ) and (Δ_{adj}) to determine whether the slope coefficients of each unit in a panel are different. Δ test is suitable for large samples and Δ_{adj} test for small samples. Unlike the Swamy's (1970) test, Pesaran and Yamagata (2008) gives reliable results for larger cross-section dimension and time dimension. The test is based on the following delta statistics:

$$\Delta = \sqrt{N}\left(\frac{N^{-1}\,\widetilde{S} - k}{\sqrt{2K}}\right) \rightarrow N(0,1), (N,T) \rightarrow \infty, \frac{\sqrt{N}}{T} \rightarrow \infty \ldots\ldots\ldots\ldots \quad (5)$$

$$\Delta_{adj} = \sqrt{N}\left(\frac{N^{-1}\widetilde{S} - E(\widetilde{Z}_{it})}{\sqrt{Var\,(\widetilde{Z}_{it})}}\right) \quad where\ mean\ E(\widetilde{Z}_{it}) = k, Var\,(\widetilde{Z}_{it}) = \frac{2k(T-k-1)}{T+1} \ldots. \quad (6)$$

Relaxing the assumption of homoscedasticity and serial independence for Pesaran and Yamagata (2008) slope homogeneity test, Blomquist and Westerlund (2013) extended the test for a more robust version that can deal with the practically relevant case of when regression errors are heteroskedastic and/serially correlated in an unknown fashion. For the purpose of this study, it is a valuable addition to Pesaran and Yamagata (2008) slope homogeneity test. The test is based on the following statistic:

$$\Delta_{HAC} = \sqrt{N}\left(\frac{N^{-1}\,S_{HAC} - k}{\sqrt{2k}}\right) \ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

$$\Delta_{HAC_{adj}} = \sqrt{N}\left(\frac{N^{-1}\,S_{HAC} - E(\widetilde{Z}_{it})}{\sqrt{Var\,(\widetilde{Z}_{it})}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

4.4. Model justification

From a theoretical point of view, both the monetarist and fiscal theories offer valuable insights into the dynamics of inflation. While the monetarist view emphasizes monetary control, the FTPL underscores the significance of fiscal discipline and debt management. Unlike the Ricardian framework, FTPL operates under non-Ricardian assumption, according to Kwon et al. (2006) the FTPL shows the potential impact of fiscal policy on price levels through the wealth effect of public debt, and the wealth effect depending on certain factors, for instance, the maturity profile of public debt, and the level of taxes or expectation of future tax increases may be effective, strong, or weak (Kwon et al., 2006). The theoretical channel of wealth effect remains valid but may be less prominent or conditional in SSA economies because of the structure of public debt, the credibility of fiscal and monetary authorities, and the degree of financial market development, where monetary policy is subordinated to fiscal needs, with inflation probably responding to changes in public debt but more through fiscal dominance or monetization, rather than the pure wealth effect.

External public debt in most Sub-Saharan African (SSA) countries are largely concessional, especially for low-income economies, even though there is a shift in recent years towards non-concessional borrowing. Concessional loans are extended on more favorable terms than market conditions, typically involving below market interest rates, longer grace periods, and longer maturities that are usually provided by bilateral donors like China or multilateral institutions like the World Bank, International Monetary Fund (IMF) and African Development Bank (AfDB). These loans are not directly perceived as domestic wealth. It is generally recognized that these arrangements by international financial institutions are aimed at supporting economic growth and macroeconomic stability (IMF, 2010).

Many SSA countries have shallow financial markets, government debt is often held by banks or foreign creditors, not widely by households in domestic economy. Consequently, changes in public debt levels may not significantly alter household wealth perception of public debt. Barro (1974, 1989) contends that fiscal deficits and public debt do not significantly influence the price level, indicating that government bonds do not constitute net wealth. He posits that public debt can diminish perceived household wealth due to uncertainty regarding future tax obligations, thereby increasing financial risk embedded in household balance sheets. More so, domestic public debt yield in most SSA and developing countries do not always reflect "true" interest rates (UNCTAD, 2016). This is primarily due to various factors such as lack of market liquidity, distortions in the financial markets, or government interventions that affect borrowing costs. These factors can influence yields and create discrepancies from the "true" market interest rates (Beaugrand et al., 2002). Thus, interpreting domestic public debt levels in terms of "true" interest rates must be done with caution. If domestic public debt does not reflect "true" interest rates, governments may over-borrow domestically, falsely believing that domestic debt is cheap and risk-free. In addition, even though Spierdijk and Umar (2015) suggest inflation hedging properties of United State bonds and treasury bills, where financial market are well developed with adequate institutional capacity necessary for the regulation and functioning of the market, investors and analysts in SSA and developing economies should be cautious or not use bond yield as reliable signals for macroeconomic fundamentals like inflation expectations or sovereign risk.

Empirically, several recent studies have argue that the wealth effect of public debt may be less prominent or conditional in SSA and developing economies. Reinhart and Rogoff (2010) argue that high level of public debt can trigger inflation through less direct channels and not necessarily via the wealth effect, especially in developing countries. Aimola and Odhiambo (2021, 2022a, 2022b) also demonstrates that the channel for the relationship between public debt and inflation is often via monetary financing or fiscal dominance, not the pure wealth effect. Buthelezi (2024), Batool et al. (2024), and Sanusi (2020) highlights the presence of fiscal dominance in sub-Saharan Africa and other developing economies. Buthelezi (2024) explains that fiscal dominance arises when

persistent government borrowing and rising public debt contribute to inflationary pressures, and it may also manifest when central banks intervene to maintain low interest rates and support government bond prices, effectively lowering the cost of public debt servicing. Hooley et al. (2024) also documents widespread fiscal dominance in SSA through central bank financing and confirms its inflationary impact via exchange rate and money growth channels. Wheeler (1999) for the United States demonstrate an extreme form of Ricardian equivalence hypothesis, suggesting that wealth falls as government debt rises. Although there is limited literature on this issue but given these findings and experiences, it is difficult to draw a general conclusion regarding the wealth effects of public debt in sub-Saharan Africa (SSA) within the context of this study. Existing literature on public debt-inflation nexus also fails to provide conclusive and consistent evidence on the wealth effects of public debt in SSA and other developing economies.

In light of this inconclusive evidence, the decision to empirically assess the causality between public debt and inflation using Konya's (2006) symmetric bootstrap panel causality approach alongside the asymmetric extension by Yılancı and Aydın (2017), based on bivariate econometric model techniques is justified. This approach, which does not impose theory-based restrictions on the relationship between variables, allows for an empirical assessment of Granger causality, particularly if the wealth effect of public debt is less prominent or muted in the region. It considers whether the information contained in one variable helps improve the prediction of the other. This consideration is particularly relevant in recent times, as the channel through which public debt affects inflation in domestic SSA economies remains a subject of active debate among scholars and policymakers.

4.5. *Symmetric and asymmetric bootstrap panel causality test*

Using a panel data approach, both symmetric and asymmetric Granger causality between public debt and inflation is investigated in this study. These tests would help determine if the past values of public debt helps predict future inflation, and vice-versa. In line with Granger (1969), public debt would be said to Granger-cause inflation if the past values of public debt contain information that helps improve the prediction of inflation, beyond what is contained in the past values of inflation alone, and vice-versa. The study adapted the methodology proposed by Konya (2006) for symmetric bootstrap panel causality test and the Yılancı and Aydın (2017) approach based on Granger and Yoon (2002) and Konya (2006) for asymmetric causality test. These approach has been recently applied in several macroeconomic studies for both symmetric and asymmetric bootstrap panel causality analysis. Our rationale for adopting Konya's (2006) technique, among others, for symmetric investigation, is the robust ability of the technique in analyzing causal relationship between variables in the presence of cross-sectional dependence and slope heterogeneity among countries in a panel. The approach developed by Konya (2006) employs the Seemingly Unrelated Regression (SUR) estimator proposed by Zellner (1962). According to Konya (2006) SUR estimator are reliable than OLS estimators if there is cross-sectional dependence among countries in the panel. Extra information are neglected using the ordinary least squares estimators making it not efficient. Konya (2006) SUR estimator for panel causality test is a more efficient estimator in generating consistent and reliable results. In addition, since the approach would use country specific bootstrap critical values, variables are not supposed to be stationary, irrespective of their time-series properties. The method also does not require preliminary testing for cointegration. Variables are employed at levels in determining causal linkages without loss of trends dynamics should they have to be use in difference form. The approach provide separate results for each country on the causal link between study variables allowing comparison across countries. Konya's (2006) approach determine causality by considering country specific Wald test statistics with country specific bootstrap critical values such that if estimated Wald test statistics is greater than bootstrap critical values, the presence of causality is established. The Wald test statistic and bootstrap critical values at 1 percent, 5 percent, and 10 percent are obtained using GAUSS codes provided by Kar et al. (2011), and Menyah et al. (2014).

Drawing largely from the studies of Konya (2006), Kar et al. (2011), and Menyah et al. (2014), the study implement the symmetric bootstrap panel causality test between public debt and inflation without decomposing the variables and estimate a bivariate Seemingly Unrelated Regression system with the following set of equation:

$$\begin{aligned} INF_{1,t} &= \varphi_{1,1} + \sum_{i=1}^{rINF_1} \beta_{1,1,i}\, INF_{1,t-i} + \sum_{i=1}^{rPD_1} \theta_{1,1,i} PD_{1,t-i} + \mu_{1,1,t} \\ INF_{2,t} &= \varphi_{1,2} + \sum_{i=1}^{rINF_1} \beta_{1,2,i}\, INF_{2,t-i} + \sum_{i=1}^{rPD_1} \theta_{1,2,i} PD_{2,t-i} + \mu_{1,2,t} \\ &\vdots \\ INF_{N,t} &= \varphi_{1,N} + \sum_{i=1}^{rINF_1} \beta_{1,N,i}\, INF_{N,t-i} + \sum_{i=1}^{rPD_1} \theta_{1,N,i} PD_{N,t-i} + \mu_{1,N,t} \end{aligned} \tag{9}$$

and

$$PD_{1,t} = \varphi_{2,1} + \sum_{i=1}^{rINF_2} \beta_{2,1,i}\, INF_{1,t-i} + \sum_{i=1}^{rPD_2} \theta_{2,1,i} PD_{1,t-i} + \mu_{2,1,t}$$

$$PD_{2,t} = \varphi_{2,2} + \sum_{i=1}^{rINF_2} \beta_{2,2,i}\, INF_{2,t-i} + \sum_{i=1}^{rPD_2} \theta_{2,2,i} PD_{2,t-i} + \mu_{2,2,t}$$

$$\vdots \qquad (10)$$

$$PD_{N,t} = \varphi_{2,N} + \sum_{i=1}^{rINF_2} \beta_{2,N,i}\, INF_{N,t-i} + \sum_{i=1}^{rPD_2} \theta_{2,N,i} PD_{N,t-i} + \mu_{2,N,t}$$

Where *INF* denotes inflation and *PD* represents public debt. φ, β and θ shows the common factors, *N* the number of countries in the panel, and *t* the time period. The error term and lag length are denoted by μ and *r*, respectively. Optimal lag testing is necessary for causality testing since the results are sensitive to lag structure. In the equation system, the maximum lags is allowed to differ across variables, but stay the same across equations. Assuming a lag between 1 and 4, the system is estimated choosing the combinations which minimize the Akaike information criterion (AIC).

Based on this study Seemingly Unrelated Regression system, according to Konya (2006) in country *i*: (i) There is one-way Granger causality running from public debt to inflation if not all $\theta_{1,i}$ are zero but $\beta_{2,i}$ are zero. (ii) There is also a one-way Granger causality from inflation to public debt if all $\theta_{1,i}$ are zero but not all $\beta_{2,i}$ are zero. (iii) There is two-way Granger causality between public debt and inflation if neither $\theta_{1,i}$ nor $\beta_{2,i}$ are zero. (iv) There is no Granger causality between public debt and inflation when both $\theta_{1,i}$ and $\beta_{2,i}$ are zero.

To analyze asymmetric causality between public debt and inflation, the study employ the method suggested by Yılancı and Aydın (2017) for panel causality test. This approach considered the studies of Granger and Yoon (2002) on hidden cointegration test and suggested for panel causality test that original data be decompose into positive and negative components to reveal hidden causal linkages by applying these components in Konya's (2006) bootstrap panel causality test.

Drawing from the studies of Hatemi-J (2012) and Yılancı and Aydın (2017) the study derive the positive and negative shocks of our study variables (PD_{it} *and* INF_{it}) in the panel in a cumulative form as follows:

$$PD_{it} = PD_{it-1} + \varepsilon_{it} = PD_{it,0} + \sum_{i=1,j=1}^{t,n} \varepsilon_{ij} \quad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (11)$$

$$INF_{it} = INF_{it-1} + \omega_{it} = INF_{it,0} + \sum_{i=1,j=1}^{t,n} \omega_{ij} \quad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (12)$$

Where $PD_{it,0}$ and $INF_{it,0}$ denote the initial values and $\varepsilon_{it} \sim N\left(0, \sigma^2_{\varepsilon_{it}}\right)$ and $\omega_{it} \sim N\left(0, \sigma^2_{\omega_{it}}\right)$ represents the disturbance terms with white noise distribution characteristics. The positive and negative shocks are define as follows:

$$\varepsilon^+_{it} = \max(\varepsilon_{it}, 0), \varepsilon^-_{it} = \max(\varepsilon_{it}, 0) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (13)$$

$$\omega^+_{it} = \max(\omega_{it}, 0), \omega^-_{it} = \max(\omega_{it}, 0) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (14)$$

With the disturbance terms, we can rewrite Equations (13) and (14) as:

$$PD_{it} = PD_{it-1} + \varepsilon_{it} = PD_{it,0} + \sum_{i=1,j=1}^{t,n} \varepsilon^+_{it} + \sum_{i=1,j=1}^{t,n} \varepsilon^-_{it} \quad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (15)$$

$$INF_{it} = INF_{it-1} + \omega_{it} = INF_{it,0} + \sum_{i=1,j=1}^{t,n} \omega^+_{it} + \sum_{i=1,j=1}^{t,n} \omega^-_{it} \ldots\ldots\ldots\ldots\ldots\ldots \qquad (16)$$

According Yılancı and Aydınn (2017) the positive and negative shocks of each variable can be written in cumulative form as:

$$PD^+_{it} = \sum_{i=1,j=1}^{t,n} \varepsilon^+_{ij}, PD^-_{it} = \sum_{i=1,j=1}^{t,n} \varepsilon^-_{ij} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (17)$$

$$INF^+_{it} = \sum_{i=1,j=1}^{t,n} \omega^+_{ij}, INF^-_{it} = \sum_{i=1,j=1}^{t,n} \omega^-_{ij} \ldots\ldots\ldots\ldots\ldots\ldots \qquad (18)$$

Given the positive and negative shocks, Yılancı and Aydın (2017) suggested that asymmetric causality can be estimated using

Konya (2006) bootstrap panel causality test on these components. As a result, the asymmetric bootstrap panel causality test is implemented if we use the positive and negative shocks instead of the original series for causality testing in Equations (9) and (10). For instance, the positive shock causal linkages in this study can be estimated using Konya's (2006) SUR system with the following set of equations:

$$\begin{aligned} INF^{+}_{1,t} &= \varphi_{1,1} + \sum_{i=1}^{rINF_1} \beta_{1,1,i} INF^{+}_{1,t-i} + \sum_{i=1}^{rPD_1} \theta_{1,1,i} PD^{+}_{1,t-i} + \mu_{1,1,t} \\ INF^{+}_{2,t} &= \varphi_{1,2} + \sum_{i=1}^{rINF_1} \beta_{1,2,i} INF^{+}_{2,t-i} + \sum_{i=1}^{rPD_1} \theta_{1,2,i} PD^{+}_{2,t-i} + \mu_{1,2,t} \\ &\vdots \\ INF^{+}_{N,t} &= \varphi_{1,N} + \sum_{i=1}^{rINF_1} \beta_{1,N,i} INF^{+}_{N,t-i} + \sum_{i=1}^{rPD_1} \theta_{1,N,i} PD^{+}_{N,t-i} + \mu_{1,N,t} \end{aligned} \tag{19}$$

and

$$\begin{aligned} PD^{+}_{1,t} &= \varphi_{2,1} + \sum_{i=1}^{rINF_2} \beta_{2,1,i} INF^{+}_{1,t-i} + \sum_{i=1}^{rPD_2} \theta_{2,1,i} PD^{+}_{1,t-i} + \mu_{2,1,t} \\ PD^{+}_{2,t} &= \varphi_{2,2} + \sum_{i=1}^{rINF_2} \beta_{2,2,i} INF^{+}_{2,t-i} + \sum_{i=1}^{rPD_2} \theta_{2,2,i} PD^{+}_{2,t-i} + \mu_{2,2,t} \\ &\vdots \\ PD^{+}_{N,t} &= \varphi_{2,N} + \sum_{i=1}^{rINF_2} \beta_{2,N,i} INF^{+}_{N,t-i} + \sum_{i=1}^{rPD_2} \theta_{2,N,i} PD^{+}_{N,t-i} + \mu_{2,N,t} \end{aligned} \tag{20}$$

Where INF^{+} is the positive component of inflation (INF) and PD^{+} the positive component of public debt (PD). All notations remain as defined in Equations (9) and (10). To save space, the negative shock causal linkages can be estimated in the same manner as Equations (19) and (20).

Similar to Konya (2006), asymmetric Granger causality can take four different forms in the system and the Wald test can be used to evaluate causal linkages. For example, the system may exhibit the following types of Granger causality for positive shocks in country i: (i) There is one-way Granger causality running from positive component of public debt to positive component of inflation if not all $\theta_{1,i}$ are zero but $\beta_{2,i}$ are zero. (ii) There is also a one-way Granger causality from positive component of inflation to positive component of public debt if all $\theta_{1,i}$ are zero but not all $\beta_{2,i}$ are zero. (iii) There is two-way Granger causality between positive component of public debt and positive component of inflation if neither $\theta_{1,i}$ nor $\beta_{2,i}$ are zero. (iv) There is no Granger causality between positive component of public debt and positive component of inflation when both $\theta_{1,i}$ and $\beta_{2,i}$ are zero. Similarly, these four types of Granger causality is also valid for negative shocks in country i.

5. Empirical results

5.1. Cross-sectional dependence and slope homogeneity tests

Before proceeding with the bootstrap panel causality test, pre-testing for cross-sectional independence and slope heterogeneity is essential. It is important to ensure the suitability of symmetric Konya's (2006) bootstrap panel causality test and Yılancı and Aydın's (2017) asymmetric approach based on Konya's (2006) bootstrap panel causality test procedure. Breusch and Pagan (1980) LM,

Table 4
Results for cross sectional dependence tests.

Test	PD ⇏ INF	INF ⇏ PD	PD^{+} ⇏ INF^{+}	INF^{+} ⇏ PD^{+}	PD^{-} ⇏ INF^{-}	INF^{-} ⇏ PD^{-}
LM_{BP}	524.961***	461.484***	650.074***	628.628***	768.212***	808.882***
CD_{LM}	32.167***	27.462***	41.441***	39.852***	50.198***	53.213***
CD	86.877***	79.395***	75.632***	75.485***	54.542***	58.807***
LM_{adj}	32.693***	28.190***	41.964***	40.342***	50.870***	53.926***

Note: *** and ⇏ denote significance at 1 % and direction of causality, respectively.
Source: Authors' compilation.

Pesaran (2004) CD_{LM} and CD, and Pesaran et al. (2008) LMadj tests results for the models are reported in Table 4. Pesaran and Yamagata (2008) (Δ) and (Δ_{adj}), and Blomquist and Westerlund (2013) (Δ_{HAC}) and $\left(\Delta_{HAC_{adj}}\right)$ slope homogeneity test results for the models are presented in Table 5. Table 4 shows unanimously for all the tests that the null hypothesis of no cross sectional dependence was rejected at the one percent significance level. This results support evidence of high integration among countries in the panel, suggesting that any shock that occurs in one country can be spread to other countries. Table 5 also reports that the null hypothesis of slope homogeneity for all the tests was rejected at the one percent significance level. This results support evidence of country-specific heterogeneity, suggesting that the directions of causal relationships among the variables may differ across countries. Therefore, country-specific findings on the causal relationships between public debt and inflation may be consider for reliable policy recommendations. The existence of cross sectional dependency and heterogeneity across countries in the panel justify the validity and suitability of this study's bootstrap panel causality approach.

5.2. Symmetric and asymmetric bootstrap panel causality test

After accounting for cross-sectional dependence and country-specific heterogeneity, this research employs the Konya (2006) panel causality test to assess the existence of a symmetric causal relation between public debt and inflation. Even though our methodology do not require pretesting for stationarity and cointegration, we inspected all variables and their decomposed components using second-generation unit root test methods proposed by Pesaran (2007), namely Cross-Sectional Augmented Dickey-Fuller (CADF) and Cross-Sectional Augmented IPS (CIPS) statistics, to ensure that none of the variables are integrated of order two [I(2)], as the presence of I(2) variables could invalidate the bootstrap inference procedure. The direction of causality is determined using bootstrapped critical values generated from 1000 replications and Wald statistics. The results of the symmetric panel Granger causality test are presented in Table 6.

As illustrated in Tables 6 and it is evident that the presence of causal linkages varies significantly across countries. The findings reveal that Lesotho and Nigeria exhibit a bidirectional causal relationship between public debt (PD) and inflation (INF), which is supported by statistically significant Wald statistics tests for both directions of causality in these countries. This outcome implies that in Lesotho and Nigeria, public debt and inflation are interconnected, suggesting that strategies aimed at reducing public debt may have a reducing impact on inflation, and vice versa, in these countries. In Ethiopia and Madagascar, a unidirectional causality is observed, specifically from public debt to inflation. The Wald statistics test confirms statistical significance, suggesting that efforts to reduce public debt in these countries would lead to a decrease in inflation. Conversely, in Equatorial Guinea and Ghana, the opposite direction of causality is evident, with causality running from inflation to public debt, as indicated by statistically significant Wald statistics tests in these countries. These findings align with similar research conducted by Taghavi (2000), Lai et al. (2015) and Wleklińska (2023) which also pointed to causal relationships between public debt and inflation in European countries. There is no symmetric Granger causality between public debt and inflation in Burkina Faso, Central African Republic, Republic of the Congo, Gabon, Kenya, South Africa, Tanzania and Togo, where the bootstrap critical values exceed the Wald statistics for these countries. Symmetric causality tests encounter a fundamental issue by assuming that both positive and negative components of variables react in the same way. Thus exploring asymmetric causality between public debt and inflation would help provide more insight into the relationship between these variables. The study for this purpose, employed Yılancı and Aydın's (2017) asymmetric panel causality test, and the findings of this test are reported in Tables 7 and 8.

As depicted in Table 7, asymmetric causality between public debt and inflation were revealed for both variables positive shocks. The test results reveal a bidirectional causality between positive shocks of public debt (PD^+) and positive shocks of inflation (INF^+) in Republic of the Congo, Ethiopia, Gabon, Madagascar, Nigeria and Tanzania. This is supported by statistically significant Wald statistics test for the two-way tests in these countries. These results suggest that positive shocks from public debt and inflation have predictive power over each other in these economies. Consequently, strategies aimed at increasing public debt may have an increasing effect on inflation in these countries. In Central African Republic, Ghana, Lesotho, and Togo a unidirectional causality exists from positive shocks of public debt to positive shocks of inflation. The Wald statistics test was also found to be statistically significant, suggesting that strategy to increase public debt may contribute to inflationary process and may be harmful to macroeconomic stability in these countries. Conversely, the reverse test from the positive shocks of inflation (INF^+) to positive shocks of public debt (PD^+) provides evidence of unidirectional causality in Burkina Faso and Equatorial Guinea. In other words, positive inflation shocks cause positive public debt shocks in these countries, as indicated by their statistically significant Wald statistics test. There is no significant causality between positive shocks of public debt and positive shocks of inflation in Kenya and South Africa, where the bootstrap critical values exceed the Wald statistics for these countries.

Table 5
Results for slope homogeneity tests.

Test	PD ⇏ INF	INF ⇏ PD	PD^+ ⇏ INF^+	INF^+ ⇏ PD^+	PD^- ⇏ INF^-	INF^- ⇏ PD^-
Δ	6.689***	7.397***	27.873***	26.409***	42.360***	31.458***
Δ_{adj}	7.027***	7.770***	29.328***	27.788***	44.571***	33.101***
Δ_{HAC}	2.887***	5.143***	19.282***	14.397***	23.727***	21.054***
$\Delta_{HAC_{adj}}$	3.033***	5.403***	20.289***	15.148***	24.966***	22.153***

Note: *** and ⇏ denote significance at 1 % and direction of causality, respectively.
Source: Authors' compilation.

Table 6
Symmetric bootstrap panel causality test results – (Konya (2006)).

Countries	H_0: PD does not cause INF				H_0: INF does not cause PD			
	Wald Stat.	Bootstrap critical values			Wald Stat.	Bootstrap critical values		
		1 %	5 %	10 %		1 %	5 %	10 %
Burkina Faso	1.26	24.53	10.29	7.08	1.63	7.36	4.85	3.93
Central African Republic	0.55	18.36	10.99	7.31	2.32	17.83	12.18	9.63
Congo. Rep. of	0.57	14.89	9.21	6.17	0.73	7.57	3.43	2.41
Equatorial Guinea	1.00	14.05	7.90	4.90	30.95***	22.21	7.36	4.90
Ethiopia	14.49**	22.86	11.21	7.90	0.37	10.91	6.00	3.82
Gabon	0.47	19.56	11.35	7.78	0.01	7.01	4.05	2.83
Ghana	0.39	12.45	6.85	4.79	14.49**	15.13	7.68	5.62
Kenya	1.72	5.14	2.64	1.75	0.04	9.38	5.19	3.64
Lesotho	24.63***	11.87	5.79	3.57	6.34*	16.92	8.72	6.14
Madagascar	7.08**	9.75	5.03	3.47	0.07	6.70	3.08	2.08
Nigeria	14.34***	10.50	4.50	3.00	4.71*	10.58	5.93	3.93
South Africa	0.15	8.90	5.33	3.75	0.06	4.57	2.30	1.55
Tanzania	1.21	8.56	6.30	5.06	0.36	5.37	2.77	1.77
Togo	0.00	20.99	13.09	9.90	1.23	27.30	5.01	2.78

Note:
1. Optimal lag length is chosen by Akaike information criterion (AIC). Assuming maximum lag length of 4.
2. ***, ** and * denote significance at 1 %, 5 % and 10 %, respectively.
3. Bootstrap critical values are obtained with 1000 replications.
Source: Authors' compilation.

Table 7
Asymmetric bootstrap panel causality test results – (Yılancı and Aydın (2017)).

Countries	H_0: PD^+ does not cause INF^+				H_0: INF^+ does not cause PD^+			
	Wald Stat.	Bootstrap critical values			Wald Stat.	Bootstrap critical values		
		1 %	5 %	10 %		1 %	5 %	10 %
Burkina Faso	2.23	10.46	7.81	6.40	6.25**	8.35	5.14	4.02
Central African Republic	9.14**	11.80	7.50	6.37	0.33	9.45	6.04	4.89
Congo. Rep. of	2.60*	6.73	3.76	2.33	3.61*	7.14	3.93	2.75
Equatorial Guinea	0.32	3.26	1.67	1.24	3.70***	3.68	2.36	1.92
Ethiopia	15.65***	1.66	1.24	1.05	7.56***	3.58	2.42	1.85
Gabon	4.64***	1.08	0.53	0.30	3.58***	1.57	1.14	0.95
Ghana	11.06***	0.42	0.25	0.16	1.38	4.97	2.71	1.89
Kenya	0.13	0.48	0.27	0.19	0.07	7.50	3.09	1.86
Lesotho	25.12***	4.23	2.25	1.49	0.33	2.22	1.26	0.86
Madagascar	3.39***	0.90	0.47	0.35	2.04*	5.14	2.58	1.79
Nigeria	21.13***	14.11	8.25	6.29	7.85***	1.29	0.81	0.59
South Africa	0.01	2.25	1.46	1.06	3.28	6.00	4.44	3.72
Tanzania	4.54***	2.26	1.34	0.87	25.29***	1.06	0.68	0.58
Togo	12.76***	11.99	10.65	10.03	6.58	21.76	18.39	16.97

Note:
1. Optimal lag length is chosen by Akaike information criterion (AIC). Assuming maximum lag length of 4.
2. ***, ** and * denote significance at 1 %, 5 % and 10 %, respectively.
3. Bootstrap critical values are obtained with 1000 replications.
Source: Authors' compilation.

The results of negative shocks Granger causality are reported in Table 8. Table 8 shows a bidirectional causality between the negative shocks of public debt (PD^-) and negative shocks of inflation (INF^-) in Burkina Faso, Gabon and Lesotho. This is supported by statistically significant Wald statistics test for the two-way tests in these countries. These results suggest that public debt and inflation are complementary in these economies. Consequently, effort to reduce the contribution of public debt to inflationary process, and vice versa, would significantly improve macroeconomic stability in these countries. In Central African Republic, Ethiopia, Nigeria and South Africa, a unidirectional causality exists from negative shocks of public debt to negative shocks of inflation. The Wald statistics test was also found to be statistically significant, suggesting that effort to reduce the contribution of public debt to inflationary process of these countries would be beneficial to macroeconomic stability. Conversely, the reverse test from negative shocks of inflation to negative shocks of public debt provides evidence of unidirectional causality from (INF^-) to (PD^-) in the Republic of the Congo, Ghana, Kenya and Madagascar, suggesting that effort towards reduce inflation could contribute to effective public debt management in these economies. There is no Granger causality between the negative shocks of public debt and the negative shocks of inflation in Equatorial Guinea, Tanzania and Togo, where the bootstrap critical values exceed the Wald statistics for these countries.

Table 8
Asymmetric bootstrap panel causality test results – (Yılancı and Aydın (2017)).

Countries	H_0: PD^- does not cause INF^-				H_0: INF^- does not cause PD^-			
	Wald Stat.	Bootstrap critical values			Wald Stat.	Bootstrap critical values		
		1 %	5 %	10 %		1 %	5 %	10 %
Burkina Faso	16.20***	8.36	4.91	3.77	9.17**	11.63	6.81	4.90
Central African Republic	18.81***	5.51	3.57	2.90	4.51	10.52	6.65	5.05
Congo. Rep. of	0.82	6.42	3.78	2.75	16.60***	8.95	5.88	4.12
Equatorial Guinea	1.01	10.20	6.14	4.28	3.08	14.34	7.08	4.52
Ethiopia	9.64**	10.87	5.99	4.33	0.95	8.02	4.65	3.10
Gabon	10.98***	8.03	4.83	3.47	11.59***	9.44	5.03	3.42
Ghana	1.62	3.88	2.58	1.96	35.72***	6.68	4.00	3.09
Kenya	0.03	2.36	1.34	0.89	15.80***	4.32	2.42	1.75
Lesotho	15.37***	2.00	1.19	0.89	6.98*	13.63	7.70	5.92
Madagascar	0.40	4.38	2.61	1.81	7.23***	4.39	2.38	1.79
Nigeria	18.02***	5.31	3.25	2.52	0.08	6.53	3.39	2.15
South Africa	9.17***	9.04	5.37	3.98	0.23	8.05	4.39	3.26
Tanzania	1.00	12.98	9.48	7.96	0.82	16.80	10.54	8.32
Togo	0.01	5.60	4.29	3.69	1.31	17.23	12.30	10.31

Note:
1. Optimal lag length is chosen by Akaike information criterion (AIC). Assuming maximum lag length of 4.
2. ***, ** and * denote significance at 1 %, 5 % and 10 %, respectively.
3. Bootstrap critical values are obtained with 1000 replications.
Source: Authors' compilation.

Table 9 provides a summary of the direction of Granger causality relationship between public debt and inflation. The significance levels of the Granger causal linkages indicated by the arrows differ among different countries. A strong causal link between public debt and inflation emerges in any country where both symmetric and asymmetric tests provide evidence of such a relationship. Furthermore, if the symmetric causality test yields insignificant results while the asymmetric causality test indicates significance, neglecting the consideration of both positive and negative shocks in the analysis of causality may fail to reveal the true causal relationship between these variables. As shown in Table 9, when symmetric relationship is taken into consideration, Granger causality from public debt to inflation is observed in four out of fourteen countries. However, when asymmetric relationship is examined, causality becomes evident in twelve out of fourteen countries. In addition, there is Granger causality from inflation to public debt when symmetric relationship is taken into consideration in four out of fourteen countries but when asymmetric relationship is taken into consideration, Granger causality is observed in eleven out of fourteen countries. While the significance levels of the Wald statistic test differ across countries, the evidence from asymmetric relationships provides stronger empirical support for the causal links between public debt and inflation. Therefore, this finding highlights hidden relationship and the importance of taking into consideration both positive and negative shocks of the variables in order to determine a robust causal relationship between public debt and inflation.

Table 9
Summary for direction of Granger causality.

Countries	Direction of causality		
	Symmetric	Asymmetric	
	Public debt (PD) and inflation (INF)	Positive components (PD^+ and INF^+)	Negative components (PD^- and INF^-)
Burkina Faso	No causality	$PD^+ \leftarrow INF^+$	$PD^- \leftrightarrow INF^-$
Central African Republic	No causality	$PD^+ \rightarrow INF^+$	$PD^- \rightarrow INF^-$
Congo. Rep. of	No causality	$PD^+ \leftrightarrow INF^+$	$PD^- \leftarrow INF^-$
Equatorial Guinea	$PD \leftarrow INF$	$PD^+ \leftarrow INF^+$	No causality
Ethiopia	$PD \rightarrow INF$	$PD^+ \leftrightarrow INF^+$	$PD^- \rightarrow INF^-$
Gabon	No causality	$PD^+ \leftrightarrow INF^+$	$PD^- \leftrightarrow INF^-$
Ghana	$PD \leftarrow INF$	$PD^+ \rightarrow INF^+$	$PD^- \leftarrow INF^-$
Kenya	No causality	No causality	$PD^- \leftarrow INF^-$
Lesotho	$PD \leftrightarrow INF$	$PD^+ \rightarrow INF^+$	$PD^- \leftrightarrow INF^-$
Madagascar	$PD \rightarrow INF$	$PD^+ \leftrightarrow INF^+$	$PD^- \leftarrow INF^-$
Nigeria	$PD \leftrightarrow INF$	$PD^+ \leftrightarrow INF^+$	$PD^- \rightarrow INF^-$
South Africa	No causality	No causality	$PD^- \rightarrow INF^-$
Tanzania	No causality	$PD^+ \leftrightarrow INF^+$	No causality
Togo	No causality	$PD^+ \rightarrow INF^+$	No causality

Note:
1. → or ← indicate direction of unidirectional Granger causality.
2. ↔ indicate direction for bidirectional Granger causality.
Source: Authors' compilation.

6. Conclusion and policy recommendation

This study investigate and compare both symmetric and asymmetric causal relationships between public debt and inflation across 14 sub-Saharan African countries, using data from 1990 to 2021. Countries analyzed include Burkina Faso, Central African Republic, Republic of the Congo, Equatorial Guinea, Ethiopia, Gabon, Ghana, Kenya, Lesotho, Madagascar, Nigeria, South Africa, Tanzania, and Togo. To account for cross-country interdependence and unique national characteristics, a bootstrap panel Granger causality test was used. Konya's (2006) methodology addressed symmetric causality, while Yılancı and Aydın's (2017) adaptation enabled testing for asymmetric causality. These methodologies helped identify previously unexplored causal relationships, providing valuable insights into the causal link between public debt and inflation across countries in the sub-region. Wald statistics were tested against country-specific bootstrap critical values obtained through 1000 replications, without the need for preliminary unit root or cointegration tests. Additionally, CPIA rankings related to debt policy and revenue mobilization efficiency were reviewed.

The study confirmed that shocks in one country often impact others, and causal links between public debt and inflation differ by country. Symmetric causality emerged in six countries, while asymmetric causality extended the findings to eight more countries, revealing hidden relationships not detected by symmetric tests. Asymmetric analysis further suggested that positive and negative shocks yield different predictive effects in these countries. The CPIA analysis demonstrated institutional differences in debt management and revenue mobilization efficiency across the region, emphasizing the importance of choosing suitable estimation techniques to assess debt-inflation dynamics accurately.

In terms of asymmetric causality, a bidirectional causality between positive shocks of public debt and positive shocks of inflation was identified in the Republic of the Congo, Ethiopia, Gabon, Madagascar, Nigeria, and Tanzania. Meanwhile, a unidirectional causality from the positive shocks of public debt to positive shocks of inflation was observed in the Central African Republic, Ghana, Lesotho, and Togo, while in Burkina Faso and Equatorial Guinea, the positive shocks of inflation appeared to cause the positive shocks of public debt. No causal relationship was found in Kenya and South Africa between positive shocks of public debt and positive shocks of inflation. Notably, effective revenue mobilization seemed to mitigate the inflationary impacts of public debt increases in these countries, nonetheless it is important to highlight for these countries that efforts at reducing inflation would contribute significantly to effective public debt management in Kenya, while efforts at reducing public debt levels would significantly reduce inflationary process in South Africa. Bidirectional causality was present in Burkina Faso, Gabon, and Lesotho, with other countries showing one-way causality in various directions for the negative shocks of public debt and inflation. Asymmetric causality tests also indicated that there is no causality between the negative shocks of public debt and negative shocks of inflation in Equatorial Guinea, Tanzania, and Togo.

The results underline causal relationship between public debt and inflation in sub-Saharan Africa, underscoring the macroeconomic stability risks of increasing public debt levels, particularly post-debt relief and COVID-19. Countries near or above the 70 % public debt-to-GDP sustainability threshold face heightened risks, though negative public debt shocks may help contribute to reducing inflationary pressures, further research is recommended to clarify the nature of influence positive shocks of public debt have on positive shocks of inflation in countries below this sustainability threshold.

From a policy perspective, controlling inflation is vital for macroeconomic stability in the sub-region where fiscal policies significantly affect inflation. The presence of cross-sectional dependence in the panel suggests a high degree of integration among the countries, indicating that shocks originating in one country may spill over to others within the sub-region. Strengthening cooperation in the coordination of fiscal and monetary policies, to reduce deficits, limit reliance on public borrowing, and enhance revenue efficiency, is therefore essential. Policies promoting taxation and local resource mobilization should be emphasized. Positioning public debt and revenue mobilization as key fiscal anchors can aid the region, enabling managed public debt levels and balanced taxation without hindering economic growth. A strategic public debt and fiscal policy framework aligned with the SDGs and African Union Agenda 2063 is advised. A comprehensive understanding of symmetric and asymmetric debt-inflation relationships will enhance inflation forecasting, cautioning policymakers against unchecked increases in public debt.

Future research might explore alternative causality framework such as Dumitrescu and Hurlin (2012), Toda and Yamamoto (1995), Hatemi-J (2012), frequency domain approaches, wavelet-based causality tests, and others, to determine whether their findings differ significantly from those reported in this paper. Additionally, analyzing disaggregated public debt data could illuminate how external and domestic public debt distinctly influence inflation across countries in sub-Saharan Africa.

CRediT authorship contribution statement

Akingbade U. Aimola: Writing – review & editing, Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Nara Monkam:** Writing – review & editing, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Funding statement

The authors received no grant/financial support for the research, authorship, and/or publication of this article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to

influence the work reported in this paper.

Data availability

The study primarily relies on data for public debt, inflation rates, and Country Policy and Institutions Assessment (CPIA) rankings focused on debt policy and revenue mobilization efficiency. Public debt data used to support the study's findings is openly available in the International Monetary Fund (IMF) DataMapper database at https://www.imf.org/external/datamapper/d@FPP/USA/FRA/JPN/GBR/SWE/ESP/ITA/ZAF/IND?year=2022 ©IMF, 2023. Data for inflation rates and CPIA on debt policy and revenue mobilization efficiency were freely accessible from the World Bank's World Development Indicators 2023 at http://databank.worldbank.org/data/source/world-development-indicators. Both databases were accessed March 20, 2023. Data will be made available on request.

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