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## Article

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# Effects of public debt on public infrastructure investment in Ghana

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## ABSTRACT

Though studies abound on the relationship between public debt and other macroeconomic variables, research on the effects of public debt on government infrastructure investment, particularly in Ghana has not received much scholarly attention. Therefore, this relationship is explored in this study by using the Non-linear Autoregressive Distributed Lagged (NARDL) model for an annual dataset from 1983 to 2020. The findings indicate a positive correlation between foreign debt and infrastructure investments in both the short-run and the long-run suggesting that foreign debt have more significant impact on public infrastructure investment than domestic debt, highlighting the crucial role of foreign debt in financing Ghana's infrastructure investments. In the long-run, the study finds a positive asymmetric link between foreign debt and public infrastructure. In particular, a rise in public infrastructure investment by 3.1% increases external debt by 1.3% as foreign debt has a higher effect on public infrastructure investment in the long term. Additionally, public expenditure has a positive effect on public infrastructure investment in the long run whereby a 1% increase in public spending leads to 2.06% rise in public infrastructure investments. The study further identifies a positive asymmetric impact of public debt on public infrastructure investment in Ghana. For policy purposes, the study suggests that government directs public debts to economic projects through capital formation, rather than for consumption purposes. It further advocates for prudent debt management by investing more in capital projects to enhance production and good returns.

## IMPACT STATEMENT

This study examines the relationship between public debt and public infrastructure investment in Ghana by adopting a Non-linear Autoregressive Distributed Lagged (NARDL) model for a data spanning 1983 - 2020. The findings of the study reveal that there is a positive relationship between public debt and infrastructure investments in the short-run and the long-run. The study further reveals that there exists a positive asymmetric impact of public debt on public infrastructure in Ghana. The study suggests that political and economic decision-makers should enhance public debt expansion for positive effect on infrastructure. The main policy suggestion of this study is that Government should set up systems to monitor borrowed funds, improve debt management by allocating more resources to essential public infrastructure as well as ensuring that foreign loans are invested in projects that yield sufficient returns.

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## 1. Introduction

The global economic downturns in the early 1980s led to irresponsible lending, inefficient debt management, and a widespread debt crisis. Emerging countries accumulated substantial debt for infrastructural projects and for ensuring macroeconomic stability which resulted in loan repayment difficulties and tax imposition challenges. This impeded economic growth as countries pursued long-term objectives while accruing new debt. Throughout history, Ghana has faced a persistent challenge of escalating national debt, hindering its economy. Over the past three decades, the debt has consistently risen to seemingly insurmountable levels leaving the country vulnerable to financial crises, primarily due to substantial

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foreign debt, pointing to fiscal leakages, inefficient debt management, and inadequate cash management as key contributors to the economic predicament (IMF, 2017).

Ghana's 2020 Public Debt Report reveals a rise to 76.1% of GDP, surpassing the ECOWAS sub-regional average of 70%. The escalating debt, coupled with unsustainable servicing costs, poses a threat to the economy. A significant portion of national income allocated to debt repayment contributes to a worsening infrastructure deficit and susceptibility to shocks. The total debt, divided into domestic and international, shows a recent shift with over 50% being domestic in 2020. Ghana's total debt comprises domestic and international debt. Historically, high government borrowing led to a significant portion being foreign debt before a reduction in 2004. Recently, the proportion of external debt has decreased, with over 50% of the public debt being domestic as of December 2020. In 2020, domestic debt increased to 51.4%, while foreign debt decreased to 48.6%, according to the Ministry of Finance. Ghana's national debt is substantial compared to its small public investment in infrastructure projects. Despite a rise in public investment as a share of GDP from 1990 to 2000, government spending decreased from 2000 to 2019.

Public investments in infrastructure are considered crucial for economic growth, with potential fiscal multiplier effects. Debt-to-GDP ratio changes depending on the fiscal multiplier and income-to-output elasticity. In Ghana, insufficient domestic savings, inefficient tax system, and political reluctance to borrowing hinder revenue generation. However, public infrastructure projects often rely on debt financing due to their size and longer lifespan. In view of the above challenges, Ghana is faced with inadequate infrastructure investment. On the other hand, public infrastructure investment is seen as essential for job creation and poverty reduction, but Ghana's vulnerability to macroeconomic uncertainties including public debt limits infrastructure spending in terms of quality and quantity. Ghana faces low standard infrastructure compared to other developing nations which get in the way of economic growth. Historical economic programs in the 1980s laid the foundation for growth, but persistent debt levels that have soared in recent times and threatens to exceed sustainability levels are a major concern for policy makers. Existing studies have generally shown the negative effect of public debt on public infrastructure investment. However, the exact relationship between government debt and infrastructure investment in Ghana has not received much scholarly attention, hence the need to document some empirical findings in the current study. As such, this research attempts to examine the relationship using a nonlinear autoregressive distributed lag (NARDL) technique to validate the short-term and the long-term symmetric effects of public debt on public infrastructure investment.

The findings of the study would inform discussions on public debt sustainability and infrastructure investment, particularly in roads, railways, water systems, and sewage treatment plants. It also contributes to understanding key determinants of public infrastructure investment in Ghana and provides guidance for effective infrastructure project management with borrowed funds.

The rest of the study is organized into four sections as follows: section one covers introduction, section two reviews the literature, section three deals with the methodology, while section four reports the empirical results with its discussions, and the last section concludes the study with policy suggestions.

## 2. Literature review

The study explores the impact of public debt on infrastructure investment in Ghana, focusing on the neo-classical growth model. It considers various indicators to gauge the economic impact of public debt, emphasizing the potential effects on domestic savings and public investment. The paper theoretically examines the interconnectedness between government debt and infrastructure investment, drawing inspiration from the debt overhang theory as well as the liquidity constraints and the dual gap hypotheses.

Myers (1977) first developed the debt overhang theory and its main idea is that at some point, a country's level of debt gets so high that it prevents further investment in public infrastructure, stunting the country's economic development. According to Udeh et al. (2016), the burden becomes so great that the majority of the country's income is spent on debt repayment rather than on investments in items like new infrastructure. As such, sovereign governments are affected by debt and in this context, the term refers to a state in which a country's debt levels surpass its projected income. This might be due to the economy's inability to fill available jobs or a continual demand for more credit to address a

production deficit. A large debt burden may stifle economic growth and lower standards of life by diverting resources away from essentials like healthcare, education, and infrastructure.

On the liquidity constraint hypothesis, it stipulates that capital market imperfections limit the amount of money an individual may borrow or the interest they may pay. The idea of liquidity restrictions suggests that debt repayment may reduce resources that may otherwise be available to be invested in economically beneficial projects. Poor investment in high-debt emerging nations is due to liquidity constraints, not debt overhang as argued by Hoffman and Reisen (1991). This position is further stressed that a debt liquidity limit should be legally enforced since interest and principal payments reduce the amount of money available for investment (Fosu, 1999). Without access to international financial markets, nations have a liquidity constraint that makes it difficult to make up for shortfalls in private budgetary financing and foreign currency revenues (Serieux & Yiagadeesen, 2001). Given that the vast majority of African countries' loans come from foreign governments, determining the effectiveness of their public debt (especially external debt) is often their biggest challenge.

The dual-gap hypothesis also suggests that a developing country may expect to achieve its economic growth objectives with a predetermined amount of borrowing. The hypothesis, according to Presbitero and Panizza, views investment as a function of savings meaning that the capital-output ratio and the savings rate are both important factors in determining economic growth. However, external assistance and domestic savings cannot be substituted, as a result, even if savings are raised to make the intended investment, it will still require the necessary import of capital goods to enhance productivity. Therefore, foreign currency deficit to buy capital goods cannot be remedied by increasing savings. Hence, this creates a gap between foreign exchange and savings to achieve targeted growth rates. Developing nations are particularly affected by this shortage since they are unable to boost exports. Therefore, the two-gap hypothesis explains why savings and foreign currency are not interchangeable, so the lack of local savings or access to foreign cash is a major challenge for developing countries. External sources of funds are vital to finance the infrastructure needs required to drive growth and to make up for the insufficient level of local savings.

On the empirical front, specific studies that have investigated the relationship between government debt and investment include, Chukwu et al. (2021) which focus on Nigeria from 1985 to 2018. By analyzing the impact of public debt on public investments using the Auto-Regressive Distributed Lag (ARDL) model and co-integration test, the study concludes that, in Nigeria, public debt has no significant impact on public investment. Thilanka and Ranjith (2018) studied the relationship between public borrowing and investment in Sri Lanka's economy from 1978 to 2015. The research focused on a model with a few key variables, including investment, foreign debt, domestic debt, and real GDP. Utilizing the Johansen co-integration approach and the Vector Error Correction Model (VECM), the authors examined short- and long-term connections between public debt and both domestic and international investment. The findings suggest a positive correlation between government debt (both domestic and foreign) and investment. This contradicts a cross-national study by Clements et al. (2003), which suggested that countries with high levels of foreign debt, like Sri Lanka, tend to be less inclined to invest. Thilanka and Ranjith (2018) concluded that Sri Lanka experienced benefits from both domestic and international borrowing.

Prompted by the renewable energy funding challenge in sub-Saharan Africa, Onuoha et al. (2023a) examine the moderating role of governance quality in the relationship between public debt and renewable energy consumption (REC) in the region using the Feasible Generalized Least Squares. The study established that public debt positively impacts REC, but the interactive effect of governance quality and public debt impedes REC. Therefore, there is a need to address the funding challenges of transitioning to a green energy future in SSA by highlighting the critical role of governance. In a related study titled 'Sustainability burden or boost? examining the effect of the public debt on renewable energy consumption in sub-Saharan Africa', Onuoha et al. (2023b) opined while renewable energy has a negligible impact on environmental degradation, developing regions like sub-Saharan Africa (SSA) is restricted by the capital-intensive investment requirements of the burgeoning renewable energy market. So, to explore the significance of available funding sources on renewable energy development in the region, their study investigates the influence of public debt on renewable energy consumption (REC) in a panel of 29 SSA countries, in full and sub-regional categorizations. Both the instrumental variable generalized method of moment (IV-GMM) approach and the two-stage least squares estimators are employed to analyse the data. Generally, the findings indicate that public debt, carbon emission, financial development, and economic growth negative

and significant effect on renewable energy, while urbanization has a positive and significant influence. Therefore, the study suggests an improvement in the debt-financed funding for the development of the renewable energy sector in SSA.

Okere et al. (2023), in their study to find the connection between public debt and energy poverty in 30 sub-Saharan African countries from 2007–2018, a composite energy poverty index was developed using the principal component analysis. The relation to public debt via the Instrumental Variable Generalized Method of Moments approach. Additionally, the effects of a debt threshold are taken into account and their implications for the region's energy poverty are assessed. The main finding of the study reveals that public debt has a positive and significant linear effect on the energy poverty index, national electricity access, urban electrification, rural electrification, and access to clean cooking fuels while it reduces renewable energy production and utilization. The study recommends a reduction in energy poverty through sustainable public debt management.

Al-Dughme (2019) examined the impact of government borrowing and spending in Jordan from 1990 to 2017 using multiple linear regression analysis. The study finds an inverse relationship between government debt and expenditures. Sánchez-Juárez and García-Almada (2016) analyzed public debt, public investment, and economic development in Mexican state governments from 1993 to 2012. They utilized dynamic panel data models and the generalized method of moments (GMM) considering indicators, such as total population, GDP, GDP per capita, public investment, debt, government spending, foreign direct investment (FDI), and educational attainment. The findings suggest that higher national debts correlate with increased government expenditure, tax revenue, and economic growth indicating Mexico's use of public debt to stimulate growth and investment.

Ncanywa and Masoga (2018) investigated the impact of South Africa's public debt on public investment and its subsequent effect on economic growth from 1995 to 2016. They employ autoregressive distributive lag, Granger causality, impulse response function, and variance decomposition techniques. The study reveals a long-run inverse relationship between public debt and investment. Oke and Sulaiman (2012) utilized multiple linear regression analysis to examine the relationship between Nigeria's foreign debt, investment, and GDP growth from 1980 to 2008. The study drew inspiration from the model developed by Elbadawi et al. (1997) and considered factors, such as gross domestic product, private investment, government investment, exchange rate, debt service, and reserve to foreign debt. The findings indicate that increases in government expenditure significantly contribute to both economic growth and escalating national debt. Private investment was more likely with higher external debt and trade openness, but the reverse was also true. Kamundia (2015) examined the impact of Kenya's public external debt on private investment and GDP growth. The study utilizes the endogenous growth model proposed by Ghura and Hadjimichael, which suggests that government actions, including debt issuance, contribute to GDP growth. Evaluating various factors from 1980 to 2013, including economic growth, trade openness, real interest rate, inflation, public debt, debt service, investment, human capital, and population growth, the study concludes that public debt significantly affects GDP growth but has a lesser impact on private investment.

Ogunjimi (2019) used the ARDL technique to assess the long- and short-run effects of various components of Nigeria's state debt on investment behavior from 1981 to 2016, considering both domestic and international investments. Private capital, public capital, and FDI were analyzed separately due to their distinct natures. GDP and interest rate were also considered. The study found that despite its positive effects on public and private investment, domestic debt had a negative impact on FDI. The conclusion drawn was that any form of government debt, whether long or short term, is detrimental to investment. Lora and Olivera (2007) conducted a panel research study on 50 countries from 1985 to 2003, investigating the impact of total public debt on social expenditure. The findings revealed that as debt levels increased, cuts to social care budgets also rose. The study highlighted a negative causal relationship between public debt and investment, emphasizing the impact of rising interest rates on reducing spending on public services and charitable organizations. Clements et al. (2003) investigated the link between external debt, government spending, and GDP growth across 55 developing nations from 1970 to 1999. Using the Barro growth model and fixed effect and system Generalized Method of Moments (GMM) estimation techniques, the study explored various economic indicators. The findings suggested that reducing foreign debt in these countries could lead to increased public investment and GDP growth, challenging the notion of convergence predicted by the debt overhang hypothesis.



Picarelli et al. (2019) assessed the crowding-out effect of public debt on public investment in 26 European countries using the Generalized Method of Moments (GMM). Supporting the debt overhang hypothesis, they find that a 1% increase in EU public debt correlated with a 3% decrease in public investment. Fagbemi and Olatunde utilized GMM dynamic panel data to explore the impact of public debt on domestic investment in 33 SSA nations from 2000 to 2017, suggesting that high national debt levels make investors cautious. Mahdavi (2004) examined data from 47 nations between 1972 and 2001 to investigate the impact of a country's total foreign debt on the central government's spending across different sectors of the economy. The findings indicated that debt serves as a hindrance to investment. Turrini (2004) empirically investigated the relationship between the introduction of the EU fiscal framework and public investment in 14 EU countries. The panel data analysis revealed an unclear impact of EU fiscal discipline rules. However, it indicates that public investment was more negatively affected by debt levels after phase II of EMU.

It is evident from the literature that most studies primarily focus on the impact of public debt on economic growth in Africa and other countries with limited attention on the connection between public debt and investments in public infrastructure, particularly in Ghana. Others also relate public debt to renewable energy investment issues in SSA by adopting panel data analysis techniques. This study therefore analyzes how Ghana's growing public debt affects its ability to finance current and future public infrastructure projects by employing the non-linear ARDL technique for the estimations.

### 3. Methodology and data

#### 3.1. The theoretical framework

The study employs the revised neoclassical model which illustrates the role of government debt and investment on economic growth as used by Owusu-Nantwi and Erickson (2016). It specifically expresses the relationship between spending and debt in a production function as follows:

$$Y_t = F(K_t, Z_t, L_t, S_t) \quad (1)$$

where  $Y_t$  (aggregate output) is a function of  $K_t$  (private capital),  $Z_t$  (public capital),  $L_t$  (labour unit), and  $S_t$  (vector of other variables that determine output). The subscript  $t$  indicates the time period. The production function has the following characteristics:  $F_x > 0$  and  $F_{xx} < 0$  where  $x = \{K_t, Z_t, L_t, S_t\}$ . This denotes the conventional assumptions for diminishing marginal returns.

From Solow, savings is a fixed fraction of income, therefore:

$$S_t = sY_t \quad (2)$$

where  $S_t$  and  $s$  denote savings and Marginal Propensity to save (MPS), respectively. The model assumes that savings are used to pay taxes or to finance both private and public investments. Therefore, we have the expression:

$$sY_t = I_{K,t} + p_z I_{Z,t} + T_t \quad (3)$$

where  $I_{K,t}$  represents an investment in private capital,  $I_{Z,t}$  is the investment in public capital,  $T_t$  is taxes. Taxes  $T_t$  in this model is assumed to be a lump sum. The variable  $p_z$  denotes the relative efficiency of public investment in terms of national output, as defined by institutional variables. A higher  $p_z$  value suggests inefficient public investment and vice versa.

The movement equation of these variables can be stated as follows when the level of both public and private investment changes:

$$\Delta K_{t+1} = I_{K,t} - \delta_K K_t \quad (4)$$

$$\Delta Z_{t+1} = I_{Z,t} - \delta_Z Z_t \quad (5)$$

where  $\delta_K$  and  $\delta_Z$  denote the depreciation rates of private and public capital, respectively, and  $0 < \delta_K, \delta_Z < 1$ . Assuming that the initial levels of both public and private investments are zero (at  $t = 0$ ), we get:

$$K_{t+1} = \sum_{s=0}^t (I_{K,s} - \delta_K K_s) \quad (6)$$

$$Z_{t+1} = \sum_{s=0}^t (I_{Z,s} - \delta_Z Z_s) \quad (7)$$

Solving for  $I_{K,t}$  from Equation (3) and substituting it into Equation (6) gives:

$$K_{t+1} = \sum_{s=0}^t (sY_t - p_z I_{Z,t} - T_t - \delta_K K_s) \quad (8)$$

Forwarding the output equation by  $t = 1$ , we have:

$$Y_{t+1} = F(K_{t+1}, Z_{t+1}, L_{t+1}, S_{t+1}) \quad (9)$$

Substituting both Equations (7) and (8) into Equation (9) gives:

$$Y_{t+1} = F\left(\sum_{s=0}^t (sY_t - p_z I_{Z,t} - T_t - \delta_K K_s), \sum_{s=0}^t (I_{Z,s} - \delta_Z K_s), L_{t+1}, S_{t+1}\right) \quad (10)$$

Given that the government is subject to the following fiscal constraints:

$$G_t + I_{Z,t} = \Delta D_t + T_t \quad (11)$$

$$\Delta D_t = G_t + I_{Z,t} - T_t \quad (12)$$

where  $G_t$  denotes government spending and  $\Delta D_t$  denotes the change in public debt. Substituting this into Equation (10), we have:

$$Y_{t+1} = F\left(\sum_{s=0}^t (sY_s - T_s - G_s - \delta_K K_s) - p_z \Delta D_t, D_t, \sum_{s=0}^t T_s - G_s - \delta_K K_s, L_{t+1}, S_{t+1}\right) \quad (13)$$

Taking derivatives with respect to  $D_t$  gives:

$$\frac{dY_{t+1}}{dD_t} = \frac{\partial F}{\partial Z} - p_z \frac{\partial F}{\partial K_p} \quad (14)$$

$$\frac{dI_{Z,t}}{dD_t} = \frac{\partial F}{\partial Z} > 0 \quad (15)$$

$$\frac{dI_{K,t}}{dD_t} = -p_z \frac{\partial F}{\partial K_p} < 0 \quad (16)$$

Equation (14) denotes the effect of public debt on public investment. The model suggests that increased public debt leads to increased public investment.

Equation (15) represents the effect of public debt on private investment. The model predicts a negative link between public debt and private investment.

From Equations (14) and (15), the effect of public debt on output Equation (13) is ambiguous, with the direction of change determined by the magnitude of both  $\frac{\partial F}{\partial Z}$  and  $p_z \frac{\partial F}{\partial K_p}$ . This renders Equation (13) ambiguous indicating that public debt could have positive, negative, or no effect on investment.

### 3.2. Model specification

Based on the above theoretical framework, the model specification is expressed as follows:

$$GFCF_t = \beta_0 + \beta_1 ED_t + \beta_2 \exp_t + \beta_3 INV_t + \beta_4 INF_t + \beta_5 EXR_t + \beta_6 TRADE_t + \beta_7 POP_t + \varepsilon_t \quad (17)$$

where  $INF_t$  = Inflation rate,  $ED_t$  = External Debt as a share of GNI,  $TRADE_t$  = Trade Openness,  $EXP_t$  = Public Expenditure per GDP,  $GFCF_t$  = Public Investment as a share of GDP,  $EXR_t$  = Exchange rate,  $INV_t$  = Private Investment as a share of GDP,  $POP_t$  = Population growth rate,  $\beta's$  are parameters to be estimated,  $\varepsilon_t$  is the random error term (white noise) and  $t$  denotes time.

### 3.3. Nonlinear autoregressive distributed lag (NARDL) bounds test for cointegration

Non-linear Autoregressive Distributed Lag (NARDL) test of cointegration approach was developed by Shin et al. (2014) to estimate both short-term and long-term associations. The adopted bounds testing methodology may be used on stationary, non-stationary, or mixed time series vectors. This is doable if the variables are all I(0)s, all I(1)s, or a mix of the two, but it is impossible if the variables are all I(2)s. In this study's limited sample size, the NARDL model proved to be an effective estimation technique for dealing with endogeneity issues. The NARDL distinguishes between how the dependent variable ( $Y_t$ ) responds to changes in the independent variables ( $x_t$ ), both positive and negative. NARDL divides the independent variable  $x_t$  into two components to account for the effect of asymmetry:



1. Partial sum of positive change in  $x_t$ , denoted by  $xt^+$ .
2. Partial sum of negative change in  $x_t$ , denoted by  $xt^-$ .

Both  $xt^+$  and  $xt^-$  are included as separate regressors in the NARDL model.

The approach may be used to determine the precise number of cointegration vectors.

$\Delta y_{t-i}$  denotes some lags of the first difference of  $y$ .

$\Delta x^+_{t-i}$  represents current plus some lags of the first difference of  $x^+$ .

$\Delta x^-_{t-i}$  represents current plus some lags of the first difference of  $x^-$ .  $y_{t-1}$  represents the first lag of  $y$ .

$x^+_{t-1}$  represents the first lag of the partial sum of positive change in  $x$ .

$x^-_{t-1}$  represents the first lag of partial sum of negative change in  $x$ .

NARDL short run coefficients:  $\lambda_i$ ,  $\delta^+$ ,  $\delta^-$

NARDL long run coefficients with asymmetric terms:  $\rho$ ,  $\Phi^+$ ,  $\Phi^-$

Disturbance term (white noise):  $\mu t$

NARDL bounds test for asymmetric long run cointegration is similar to the ordinary ARDL bounds test, it's a joint test of all lagged one-period levels of  $x^+$ ,  $x^-$ , and  $y$ .

- $F$ -test of Pesaran et al. or Narayan, if using small  $n$ :

$$H_0 : \rho = \Phi^+ = \Phi^- = 0$$

- $t$ -test of Banerjee et al.

$$H_0 : \Phi = 0$$

$$H_A : \Phi < 0$$

Therefore, if we reject  $H_0$  (of no cointegration), we conclude that the variables are cointegrated in the presence of asymmetry.

We calculate the NARDL long run levels asymmetric coefficient by dividing the negative of the coefficient of  $x^+t$  (i.e.  $\Phi^+$ ) by the coefficient of  $y_{t-1}$  (i.e.  $\rho$ ):  $\frac{-\Phi^+}{\rho}$  and also by dividing the negative of coefficient of  $x^-t$  (i.e.  $\Phi^-$ ) by the coefficient of  $y_{t-1}$  (i.e.  $\rho$ ):  $\frac{-\Phi^-}{\rho}$ .

### 3.3.1. Wald test of long run asymmetry

If a long run relationship exists (bounds test), the study proceed to test if the difference in the asymmetric coefficients are statistically significant:

$$H_0 : \frac{-\Phi^+}{\rho} = \frac{-\Phi^-}{\rho} \quad H_A : \frac{-\Phi^+}{\rho} \neq \frac{-\Phi^-}{\rho}$$

Therefore, if we reject  $H_0$ , it means we have long run asymmetry. In other words, the magnitude of the change in  $y$  when  $x$  increase is not the same as when  $x$  decrease.

## 3.4. Data

The study uses data from 1983 to 2020 which is sourced from the International Monetary Fund's World Economic Outlook, 2021 and the World Bank's World Development Indicators as well as International Financial Statistics online databases. Table 1 presents a summary description of variables used in the model, their expected signs, and data sources.

## 3.5. Model variables

## 3.6. Estimation techniques

The empirical analysis begins with unit root test for the time series data to ascertain its stationarity by using Augmented Dickey–Fuller and Phillips–Perron (1988) unit root methods. Conducting this test is essential for mitigating spurious autocorrelation associated with time series data. According to Dickey

**Table 1.** Summary of model variables, expected signs, and data sources.

| Variable                 | Measurement   | Expected sign | Source           |
|--------------------------|---|---------------|------------------|
| Public investment (GFCF) | Government gross fixed capital formation (%GDP)       |               | WDI (World Bank) |
| External debt (ED)       | Central government debt (%GDP)                        | Uncertain     | WDI (World Bank) |
| Public expenditure (EXP) | Government total expenditure (%GDP)                   | Uncertain     | WEO (IMF)        |
| Private investment (INV) | Private gross fixed capital formation (%GDP)          | Uncertain     | WDI (World Bank) |
| Inflation rate (INF)     | Consumer price index (%)                              | (-)           | WDI (World Bank) |
| Exchange rate (EXR)      | Real effective exchange rate (adjusted for inflation) | Uncertain     | WDI (World Bank) |
| Trade openness (TRADE)   | Sum of exports and imports as share of GDP            | (+)           | WDI (World Bank) |
| Population growth (POP)  | Annual population growth rate (%)                     | (+)           | WDI (World Bank) |

Source: Authors' own compilation.

**Table 2.** Results of the augmented Dickey–Fuller stationarity test.

| Variable | Level form      |                   | First difference |                    | Order of integration |
|----------|-----------------|-------------------|------------------|--------------------|----------------------|
|          | Test statistics | 5% Critical value | Test statistics  | 5% Critical values |                      |
| GFCF     | -2.791          | -2.943            | -5.867**         | -2.946             | I (1)                |
| ED       | -1.243          | -2.946            | -4.809**         | -2.948             | I (1)                |
| EXP      | -0.249          | -2.943            | -4.334**         | -2.957             | I (1)                |
| INV      | -1.880          | -2.943            | -7.929**         | -2.946             | I (1)                |
| INF      | -8.152***       | -2.943            |                  |                    | I (0)                |
| EXR      | -56.746**       | -2.943            |                  |                    | I (0)                |
| TRADE    | -2.490          | -2.943            | -5.640**         | -2.948             | I (1)                |
| POP      | 0.355           | -2.951            | -6.905**         | -2.951             | I (1)                |

Null hypothesis ( $H_0$ ): has a unit root (non-stationary); Alternate Hypothesis ( $H_1$ ): no unit root (stationary).

\*\*\*, \*\*Rejecting the null hypothesis at 1 and 5%, respectively.

Source: Author's compilation.

and Fuller (1979), the findings may be biased if the sample data present non-stationary characteristics. The Dickey–Fuller test is valid in large samples while the Phillip–Perron test shows that the null hypothesis is trend stationary rather than the presence of unit root.

The Augmented Dickey–Fuller (ADF) test can be expressed as follows:

$$\Delta x_t = \beta' D_t + \pi x_{t-1} + \sum_{i=1}^p \psi_i \Delta x_{t-1} + \varepsilon_t \quad (18)$$

Where  $x_t$  is the variable at time  $t$

$D_t$  is a vector of predictable terms that comprises a constant, trend, and so on.

$P$  is the number of lagged differences in the model.

$\pi$  and  $\psi_i$  are the coefficients to be estimated.

$\varepsilon_t$  is the random error (disturbance) term.

The tests' null and alternative hypotheses are as follows:

$H_0$ :  $\pi = 0$  (series has a unit root)

$H_0$ :  $\pi \neq 0$  (series has no unit root)

The Augmented Dickey–Fuller (ADF) and Phillip–Perron (PP) tests employ distinct strategies to adjust for serial correlation. To adjust for serial correlation, the ADF regression specification employs lagged differences in the variables, whereas the PP technique uses semi-parametric statistical methods.

## 4. Empirical results

### 4.1. Unit root test results

The study employs the use of Augmented Dickey–Fuller (ADF) and Phillip–Perron (PP) tests to identify the variables' stationarity at levels and first difference. Tables 2 and 3 summarize the results of the tests. The unit root test is used to confirm variable stationarity, crucial in time series analysis to avoid spurious regression. Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests were employed, ensuring that the model's error components are independent. Results in Table 2 from the ADF test indicate that, except for INF and EXR, all variables are integrated in order 1. Phillip–Perron test results from Table 3 show

**Table 3.** Results of the Phillip–Perron stationarity test.

| Variable | Level form      |                   | First difference |                        | Order of integration |
|----------|-----------------|-------------------|------------------|------------------------|----------------------|
|          | Test statistics | 5% Critical value | Test statistics  | 5, 10% critical values |                      |
| GFCF     | −2.772          | −2.943            | −6.036**         | −2.946, −2.613         | I (1)                |
| ED       | −1.576          | −2.946            | −4.868**         | −2.948, −2.613         | I (1)                |
| EXP      | −0.202          | −2.943            | −5.651**         | −2.946, −2.612         | I (1)                |
| INV      | −1.595          | −2.943            | −18.698**        | −2.946, −2.612         | I (1)                |
| INF      | −7.524**        | −2.943            |                  |                        | I (0)                |
| EXR      | −36.268**       | −2.943            |                  |                        | I (0)                |
| TRADE    | −2.490          | −2.943            | −6.073**         | −2.946, −2.612         | I (1)                |
| POP      | −0.593          | −2.943            | −3.450***        | −2.946, −2.612         | I (1)                |

Null hypothesis ( $H_0$ ): has a unit root (non-stationary); Alternate Hypothesis ( $H_1$ ): no unit root (stationary).

\*\*\*, \*\*Rejecting the null hypothesis at 1 and 5%, respectively.

Source: Authors' estimation from EViews.

**Table 4.** Bounds  $F$ -test results for the model.

| $F$ -statistic value | Lag length | Significance level (%) | Bounds critical value |       |
|----------------------|------------|------------------------|-----------------------|-------|
|                      |            |                        | I (0)                 | I (1) |
| 14.870***            | 2          | 10                     | 1.95                  | 3.06  |
|                      |            | 5                      | 2.22                  | 3.39  |
|                      |            | 1                      | 2.79                  | 4.1   |

Null hypothesis ( $H_0$ ): no cointegration; Alternate Hypothesis ( $H_1$ ): cointegration exists.

\*\*\*Rejecting the null at 1, respectively.

Source: Authors' compilation from research data.

that INF and EXR are in a stable state. The Autoregressive Distributed Lag (ARDL) model is deemed optimal for cointegration estimation, given a mix of I(0) and I(1) variables in both sets of results.

## 4.2. Maximum lag length selection

A VAR model is utilized to identify the optimal lag duration based on the minimum Akaike Information Criterion (AIC). After determining the lag structure, a cointegration test is performed, with E-Views automatically selecting the optimal lag structure. The Akaike Information Criterion (AIC) suggests ARDL as the optimal choice, with a lag structure of ARDL (1, 1, 0, 1, 1, 1, 0, 0, 1).

## 4.3. NARDL bounds $F$ -test for cointegration

The study employs the NARDL Bounds  $F$ -test to test for cointegration between the model's variables. NARDL, in contrast to ARDL, allows for asymmetric impacts of positive and negative changes in explanatory variables on the dependent variable (Shin et al., 2014). The NARDL approach, with cumulative dynamic multiplier graphs, reveals responses to both positive and negative shocks, maintaining the assumption of asymmetry. This makes NARDL preferable to ARDL, which assumes a symmetrical relationship. NARDL accommodates the nonlinear influence of independent factors on the dependent variable, addressing limitations in detecting asymmetric effects that standard ARDL might encounter. The model is straightforward yet comprehensive, capturing asymmetry in transitioning from short to long term.

Table 4 shows that the NARDL Bounds  $F$ -test has an  $F$ -statistic value of 14.870, exceeding the upper bounds critical value at the 1% significance level. This suggests that there exist cointegration of variables in the model, indicating the presence of long-run relationship among the variables in the model.

## 4.4. Long run estimates

The cointegration of variables in the model prompts the need to estimate the long-term relationships among them. Table 5 presents the results of the model's long-run estimations.

The long-term level equation from Table 5 reveals that Ghana's public infrastructure investment, External debt (ED), Public expenditure (EXP), Private investment (INV), Inflation rate (INF), Exchange rate (EXR), Trade openness (TRADE), and Population growth rate (POP) are all statistically significant either at

**Table 5.** Model results—long run level regression.

| Variables | Coefficient  | Standard error |
|-----------|--------------|----------------|
| ED_POS    | 3.921426**   | 1.407143       |
| ED_NEG    | 2.585422***  | 0.639467       |
| EXP       | 2.063820***  | 2.094537       |
| INV       | 1.864248***  | 0.362223       |
| EXR       | 4.247440**   | 1.610379       |
| INF       | 1.182617***  | 0.249528       |
| TRADE     | −4.435675*** | 0.939330       |
| POP       | 6.38166**    | 5.591375       |
| Intercept | −33.78708    | 11.72553       |

\*\* and \*\*\* indicating a significant level of 5 and 1%, respectively.

Source: By Authors from Research data.

**Table 6.** Stepwise regression results.

| Variables     | Coefficient  | Standard error |
|---------------|--------------|----------------|
| LGFCF(−1)     | −0.688240*** | 0.134072       |
| LED_POS(−1)   | −1.125648*** | 0.297123       |
| LED_NEG(−1)   | 0.123718*    | 0.068556       |
| LEXP(−1)      | 0.262656     | 0.171552       |
| LINV(−1)      | 0.364636***  | 0.106287       |
| LEXR(−1)      | −1.319148*** | 0.336775       |
| LINF(−1)      | −0.097045*   | 0.051314       |
| LTRADE(−1)    | −0.668552*** | 0.167288       |
| LPOP(−1)      | −4.417523*** | 1.206294       |
| Intercept     | 15.60299     | 3.444799       |
| D(LINV)       | 0.391993***  | 0.072991       |
| D(LTRADE(−1)) | 0.374900**   | 0.138346       |
| D(LTRADE)     | −0.390617**  | 0.156158       |
| D(LGFCF(−1))  | 0.240855**   | 0.098549       |

\*, \*\*, and \*\*\* indicating a significant level of 10, 5, and 1%, respectively.

Source: By authors from research data.

1 or 5%. Trade openness, however, shows a negative correlation. A positive asymmetric link between public infrastructure investment and foreign debt is observed at the 1 and 5% significance levels. For every 1% increase in foreign debt (ED POS), infrastructure investment rises by 3.92%, while a 1% decrease (ED NEG) leads to a 2.59% drop.

This suggests that foreign debt significantly drives state infrastructure spending in Ghana, aligning with research on public debt's impact on investment and economic development in Mexico (Sánchez-Juárez & García-Almada, 2016). Public spending (EXP) exhibits a positive relationship, with a 1% increase resulting in a 2.06% rise in infrastructure investments. Private investment (INV) correlates positively, indicating a 1.86% increase for every 1% rise in public investment, suggesting mutual support but with some crowding-out effect.

At the 5% significance level, the long-term investment model reveals a positive correlation between exchange rate (EXR) and government-funded capital expenditures (GFCF), increasing by 4.25% with a one-point rise in the exchange rate. The model also shows a positive correlation between inflation and government spending on infrastructure at the 1% level, with a 1% rise in inflation leading to a 1.18% increase. Contrarily, trade openness (TRADE) exhibits a negative correlation, with a 1% increase associated with a 4.4% decrease in infrastructure investment, challenging the hypothesis that commerce attracts investment to Ghana.

Lastly, at the 5% significance level, the model indicates a positive link between population growth (POP) and public infrastructure investment, with a 1% increase in population resulting in a 6.38% rise. This suggests that rising populations are a primary driver of increased government spending (Chang et al., 2014; Lartey et al., 2018).

#### 4.5. Long run asymmetry: Wald test

If a long run relationship exists (bounds test), the study proceeds to test if the difference in the asymmetric coefficients is statistically significant.

Table 6 presents the results of the stepwise regression, offering the parsimonious asymmetric error correction output. Long run terms are above the horizontal line, while short run terms are below it. All non-significant short run terms are excluded, following Shin et al. (2014), but all long run terms are retained, irrespective of significance. No evidence of a statistically significant short run asymmetric relationship between LGFCF and LED is found.

The table indicates that positive changes (POS) in external debt (ED) have a long run negative impact on LGFCF, whereas negative changes (NEG) in ED have a corresponding long run positive impact on LGFCF. This information is crucial for performing the Wald test, a coefficient test determining whether a short or long run asymmetry relationship exists. Specifically, the test assesses whether the impacts of ED\_POS and ED\_NEG are of the same magnitude (symmetric effect) or differ (asymmetric effect) (Shin et al., 2014).

Table 7 indicates that the Wald test results provide evidence of a long run asymmetry concerning external debt (ED), suggesting a non-linear relationship between public infrastructure investment and public debt (external debt) in Ghana. The statistically significant probability value of the Chi-square at the 1% significance level indicates cointegration between the variables.

#### 4.6. Short run estimation

The NARDL cointegration method is employed to assess the short-run relationship between the variables. Table 8 presents the results of the NARDL short-run regression in the study.

In Table 8, short-run regression results reveal significant impacts of public expenditure (EXP), external debt (ED), private investment (INV), trade openness (TRADE), and population growth rate (POP). A negative, significant error correction term (ECT) indicates a 71.5% return to long-run equilibrium post-shock. Notably, public infrastructure investment in Ghana is positively influenced by foreign debt, with a 1.41% increase for each 1% rise (ED POS) and a 0.83% decrease for each 1% drop (ED NEG). This contradicts Clements et al. (2003) on foreign debt discouraging investment in low-income nations. The positive link between public spending and infrastructure investment is validated at the 1% level, with a 1.31% growth in GFCF for every 1% increase in expenditure (EXP) and others. The correlation between private investment (INV) and public infrastructure spending is confirmed, indicating a 0.60% increase in GFCF for a 1% rise in INV, emphasizing a crowding-in effect. A 1% increase in population growth (POP) corresponds to a 16.48% surge in infrastructure expenditure, supporting prior research by Chang et al. (2014) and Lartey et al. (2018). However, a negative association is observed between trade openness (TRADE) and public infrastructure investment, with a 2.37% decrease for each 1% increase, corroborated in long-run equations.

#### 4.7. Discussion of main findings

The results of the long run investment equation showed that the variables, such as external debt, government spending, private investment, inflation rate, currency rate, trade openness, and population growth rate all are statistically significant. In particular, public infrastructure investment exhibited a positive correlation with foreign debt with an asymmetric positive link. In addition, public infrastructure investment is more sensitive to rising foreign debt than falling foreign debt as indicated by the cointegration estimates in Table 5. Thus, holding other things constant, public infrastructure investment (GFCF) rises 1.41% for every 1% increase in external debt (ED POS) and falls 0.83% for every 1% drop in external debt (ED NEG). This suggests that a rise in foreign debt has a higher effect on public infrastructure investment in the long term than a reduction in external debt. This finding is similar to the study by

**Table 7.** Wald test results.

| Test statistic                             | Value     | df        | Probability |
|--|-----------|-----------|-------------|
| t-Statistic                                | −5.041987 | 20        | 0.0001      |
| F-statistic                                | 25.42163  | (1, 20)   | 0.0001      |
| Chi-square                                 | 25.42163  | 1         | 0.0000      |
| Null hypothesis: $-C(3)/C(2) = -C(4)/C(2)$ |           |           |             |
| Null hypothesis summary                    |           |           |             |
| Normalized restriction (=0)                |           | Value     | Std. Err.   |
| $-C(3)/C(2) + C(4)/C(2)$                   |           | −1.815305 | 0.360038    |

Source: Authors estimation from research data.

**Table 8.** Short run regression results.

| Variables          | Coefficient  | Standard error |
|--------------------|--------------|----------------|
| ED_POS             | 1.408426**   | 0.566341       |
| ED_NEG             | −0.831750*** | 0.192799       |
| EXP                | 1.310444***  | 0.300446       |
| INV                | 0.590354***  | 0.058798       |
| EXR                | −0.321689    | 0.378328       |
| INF                | −0.070381    | 0.052970       |
| TRADE              | −2.369006*** | 0.441961       |
| POP                | 16.48436***  | 5.42648        |
| ECT <sub>t-1</sub> | −0.714693*** | 0.040444       |

\*\* and \*\*\* indicating a significant level of 5 and 1%, respectively.

Source: Authors estimation from research data.

Sánchez-Juárez and García-Almada (2016) on the effect of public debt on public investment and economic development in Mexico. Furthermore, the findings reveal that public spending and public infrastructure investment are positively related in the long run investment model for Ghana, at a significance level of 1%. So, holding other things constant, an increase in public spending (EXP) by 1% is expected to lead to a 1.31% rise in public infrastructure investments. This finding is similar to studies by Abdullah (2000), Al-Yousif (2000), Cooray (2009), and Ranjan and Sharma (2008). This finding is therefore consistent with the existing literature. This indicates that public investment in public infrastructure will safeguard and provide certain public goods for citizens, hence promoting economic growth. In addition, at the 5% level of significance, the long-term investment model reveals a positive correlation between exchange rate (EXR) and government-funded capital expenditures (FCF). Holding other things constant, it is expected that 1% increase in exchange rate, increases public infrastructure investment up by 0.32%. This position is consistent with the study by Glüzmann et al. (2012) and Mbaye (2012) but contradicts the work of Atkins (2000) and Kamin and Rogers (2000).

Moreover, there is a negative correlation between trade openness and government infrastructure investment in Ghana. By holding other factors constant, a 1% increase in trade openness is associated with a 2.4% decline in infrastructure investment. This finding does not support the hypothesis that trade is important for attracting investment to Ghana according to Barik (2013). Finally, at the 1% level of significance, the long-run investment model reveals a positive link between population and public infrastructure investment. Thus, a 1% increase in population size is expected to increase public infrastructure spending by 16.48% increase. Everything else being equal, this indicates that rising populations are one of the primary causes of increased government spending (Chang et al., 2014; Lartey et al., 2018).

In general, the long-run investment model indicates that public infrastructure investment is negatively linked to exchange rate, inflation, and trade.

The short run evidence from studies shows a negative and statistically significant link between trade liberalization and government investment in infrastructure. Thus, at the 1% level of significance, public infrastructure investment decreases by 2.37 percentage points for every percentage point that trade openness (TRADE) increases. The long run model reinforces the short run result that links trade liberalization and spending on public infrastructure.

## 5. Conclusion and recommendation

There has been a growing interest in the subject of public debt and infrastructure investment in developing countries by researchers and policy makers. However, empirical evidence on Ghana can hardly be found in the literature. This study therefore examines the relationship between public debt and public infrastructure investment in Ghana from 1983 to 2020 using a nonlinear autoregressive distributed lagged (NARDL) model. The main objective is to examine the impact of Ghana's debt servicing on public sector infrastructure investments in the long-run and the short-run. The findings show that infrastructure investment in Ghana correlates with an appreciation of the exchange rate, suggesting that allocating more foreign debt to infrastructure development can mitigate the impact of debt payment-induced exchange rate depreciation. The study further identifies a positive asymmetric impact of public debt on public infrastructure investment in Ghana, urging political and economic decision-makers to enhance public debt expansion for positive effects on infrastructure. For policy purposes, the study suggests



implementing systems to monitor borrowed funds, improving debt management to allocate more resources to essential public infrastructure, and ensuring foreign loans are invested in projects yielding sufficient returns. Based on data availability, it is imperative to include domestic debt in the public debt measurement and so the ratio of domestic debt to GDP should be considered in the policy decision making on the relation between government debt and investment in Ghana in order not to focus so much on the external debt.

The study emphasizes the importance of directing foreign money towards self-sustaining projects and discourages spending borrowed funds on non-essential goods. It encourages Ghanaian government officials to address structural imbalances and curb budget deficits for sustainable economic development.

## Authors contributions

Benjamin Frimpong: conceptualization, estimation and results interpretation, manuscript writing, and editing. Abel Fumey: conceptualization, abstract, introduction, software application, data collection, preliminary estimations, revised draft, conclusion and policy implications, manuscript writing, and editing. Edward Nketiah-Amponsah: literature review, data scrutiny, results and discussion, manuscript writing, and editing. All the authors approved the final version of the manuscript. The authors take full and collective responsibility for any omissions and commissions found in this article.

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## Data availability statement

The data that support the findings of this study are openly available at <https://databank.worldbank.org> and <https://data.imf.org>.

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## Appendices

### Appendix A: Raw data

| Year | Debt    | TRADE    | GDPC    | EXP    | GFCF    | INV     | INF      | EXR      | POP      |
|------|---------|----------|---------|--------|---------|---------|----------|----------|----------|
| 1983 | 6.0234  | 11.5449  | −7.3929 | 3.635  | 3.7612  | 3.2956  | 122.8745 | 3520.534 | 3.009472 |
| 1984 | 9.4678  | 18.8146  | 5.3888  | 4.881  | 6.8528  | 4.3713  | 39.6653  | 557.577  | 3.045216 |
| 1985 | 11.3456 | 24.2438  | 1.9845  | 6.361  | 9.5296  | 5.3716  | 10.3054  | 405.351  | 3.08096  |
| 1986 | 13.9875 | 36.7117  | 2.1528  | 7.817  | 9.2956  | 2.0133  | 24.5654  | 256.938  | 2.93853  |
| 1987 | 22.8765 | 45.8481  | 1.8009  | 7.894  | 10.3603 | 2.4180  | 39.8151  | 190.577  | 2.898628 |
| 1988 | 17.2346 | 42.2455  | 2.6364  | 7.832  | 11.2395 | 3.2151  | 31.3593  | 175.073  | 2.873176 |
| 1989 | 16.2341 | 41.0859  | 2.1108  | 7.805  | 13.1562 | 5.4005  | 25.2237  | 163.792  | 2.87201  |
| 1990 | 19.1570 | 42.7282  | 0.3922  | 7.096  | 14.3862 | 6.9211  | 37.2591  | 163.313  | 2.88324  |
| 1991 | 18.6580 | 42.4883  | 2.2766  | 7.639  | 15.8234 | 7.5299  | 18.0314  | 165.992  | 2.896004 |
| 1992 | 23.0960 | 45.9936  | 0.9198  | 9.968  | 12.7360 | 2.4487  | 10.0561  | 146.338  | 2.890408 |
| 1993 | 37.1560 | 56.6691  | 1.8984  | 13.171 | 23.7855 | 12.6779 | 24.9598  | 127.669  | 2.855531 |
| 1994 | 55.1560 | 62.0212  | 0.4625  | 13.851 | 22.5744 | 9.2766  | 24.8703  | 103.353  | 2.785186 |
| 1995 | 51.0780 | 57.4231  | 1.3442  | 13.930 | 21.1308 | 7.0823  | 59.4616  | 119.704  | 2.694865 |
| 1996 | 46.0480 | 72.2049  | 1.9162  | 13.356 | 20.2987 | 6.9903  | 46.5610  | 129.761  | 2.601561 |
| 1997 | 48.6670 | 85.4018  | 1.5987  | 12.899 | 23.8355 | 11.3934 | 27.8852  | 137.976  | 2.524705 |
| 1998 | 40.5720 | 80.5995  | 2.1442  | 12.722 | 22.3636 | 11.0604 | 14.6242  | 147.342  | 2.471693 |
| 1999 | 55.7300 | 81.7051  | 1.8738  | 11.980 | 20.4674 | 10.7131 | 12.4087  | 145.051  | 2.449458 |
| 2000 | 80.1710 | 116.0484 | 1.1908  | 12.901 | 23.0981 | 12.7013 | 25.1932  | 95.266   | 2.44949  |
| 2001 | 61.9200 | 110.0459 | 1.4834  | 14.775 | 27.1229 | 16.7133 | 32.9054  | 96.349   | 2.449526 |
| 2002 | 57.9610 | 97.4892  | 1.9738  | 11.422 | 18.7749 | 9.1929  | 14.8162  | 95.929   | 2.447185 |
| 2003 | 52.8480 | 97.2871  | 2.6452  | 12.997 | 22.9369 | 14.0000 | 26.6749  | 96.353   | 2.458459 |
| 2004 | 41.1080 | 99.6703  | 3.0086  | 14.729 | 28.3775 | 16.0000 | 12.6246  | 95.095   | 2.484618 |
| 2005 | 33.9930 | 98.1715  | 3.2673  | 13.819 | 29.0021 | 17.0000 | 15.1182  | 104.254  | 2.517456 |
| 2006 | 18.5090 | 65.9214  | 3.7165  | 15.385 | 22.9541 | 13.9000 | 10.9152  | 110.022  | 2.554408 |
| 2007 | 22.5490 | 65.3543  | 1.6891  | 17.988 | 15.3845 | 11.5000 | 10.7327  | 109.369  | 2.579994 |
| 2008 | 24.6440 | 69.5142  | 6.3711  | 17.676 | 16.4920 | 12.4000 | 16.5221  | 104.318  | 2.578728 |
| 2009 | 26.7920 | 71.5947  | 2.2111  | 17.483 | 15.4788 | 12.6000 | 19.2507  | 94.729   | 2.543839 |
| 2010 | 34.5070 | 75.3778  | 5.2493  | 19.881 | 11.7641 | 17.2000 | 10.7076  | 100.000  | 2.487042 |
| 2011 | 31.2650 | 86.2955  | 11.3154 | 19.526 | 11.9769 | 19.5000 | 8.7268   | 94.615   | 2.42437  |
| 2012 | 35.3520 | 93.1680  | 6.7336  | 21.977 | 16.1099 | 24.3000 | 7.1264   | 85.053   | 2.369475 |
| 2013 | 42.9300 | 60.7593  | 4.8475  | 21.564 | 24.0390 | 21.1000 | 11.6662  | 84.994   | 2.323852 |
| 2014 | 50.1110 | 63.8366  | 0.5258  | 20.966 | 26.4229 | 19.7000 | 15.4896  | 66.454   | 2.291781 |
| 2015 | 53.8960 | 76.5213  | −0.1700 | 18.623 | 27.0126 | 17.5000 | 17.1500  | 64.629   | 2.268815 |
| 2016 | 55.9420 | 67.8770  | 1.0770  | 19.891 | 24.8262 | 15.6000 | 17.4546  | 74.173   | 2.246599 |
| 2017 | 56.9840 | 70.5484  | 5.7543  | 17.582 | 18.8864 | 18.3000 | 12.3719  | 73.564   | 2.220532 |
| 2018 | 61.9760 | 67.9585  | 3.8966  | 20.895 | 21.1991 | 21.1000 | 7.8088   | 72.379   | 2.192829 |
| 2019 | 62.6940 | 76.8248  | 4.2292  | 21.148 | 18.0382 | 18.0000 | 7.1759   | 69.246   | 2.162578 |
| 2020 | 78.3030 | 68.0433  | −1.6051 | 28.962 | 17.6607 | 17.8000 | 9.8873   | 70.170   | 2.130763 |

Source: World development indicators.

## Appendix B: Conditional error correction regression output

Dependent variable: D (LGFCF)

Selected model: ARDL (1, 1, 0, 1, 1, 1, 0, 0, 1)

Case 3: Unrestricted constant and no trend

Date: 04/22/24 Time: 10:57

Sample: 1983 2020

Included observations: 34

### Conditional error correction regression

| Variable           | Coefficient  | Std. error | t-Statistic | Prob.  |
|--------------------|--------------|------------|-------------|--------|
| C                  | -33.78708    | 11.72553   | -2.881499   | 0.0280 |
| LGFCF(-1)          | -0.714693*** | 0.120916   | -5.910662   | 0.0010 |
| LED_POS(-1)        | 2.802615**   | 0.973558   | 2.878735    | 0.0281 |
| LED_NEG(-1)        | 1.847782***  | 0.414401   | 4.458925    | 0.0043 |
| LEXP(-1)           | 6.477848***  | 1.369548   | 4.729916    | 0.0032 |
| LINV(-1)           | 1.332364***  | 0.220857   | 6.032693    | 0.0009 |
| LEXR(-1)           | 3.035615**   | 1.178879   | 2.575002    | 0.0421 |
| LINF(-1)           | 0.845208***  | 0.198096   | 4.266656    | 0.0053 |
| LTRADE(-1)         | -3.170145*** | 0.550877   | -5.754721   | 0.0012 |
| LPOP(-1)           | 11.70785**   | 3.524704   | 3.321656    | 0.0160 |
| D(LGFCF(-1))       | -0.173268    | 0.184150   | -0.940908   | 0.3831 |
| D(LGFCF(-2))       | -1.425812*** | 0.304241   | -4.686455   | 0.0034 |
| D(LGFCF(-3))       | 0.272544**   | 0.085581   | 3.184646    | 0.0190 |
| D(LED_POS)         | 1.408426**   | 0.566341   | 2.486887    | 0.0474 |
| D(LED_POS(-1))     | 0.181156     | 0.239582   | 0.756131    | 0.4782 |
| D(LED_NEG)         | 0.831750***  | 0.192799   | 4.314086    | 0.0050 |
| D(LEXP)            | 1.310444**   | 0.300446   | 4.361657    | 0.0048 |
| D(LEXP(-1))        | -1.785165*** | 0.407489   | -4.380896   | 0.0047 |
| D(LINV)            | 0.590354***  | 0.058798   | 10.04036    | 0.0001 |
| D(LINV(-1))        | -0.652666*** | 0.104462   | -6.247890   | 0.0008 |
| D(LEXR)            | -0.321689    | 0.378328   | -0.850292   | 0.4278 |
| D(LEXR(-1))        | -1.708353**  | 0.501522   | -3.406338   | 0.0144 |
| D(LINF)            | -0.070381    | 0.052970   | -1.328683   | 0.2322 |
| D(LINF(-1))        | -0.698887*** | 0.134520   | -5.195399   | 0.0020 |
| D(LTRADE)          | -2.369006*** | 0.441961   | -5.360215   | 0.0017 |
| D(LTRADE(-1))      | 0.383315**   | 0.138265   | 2.772328    | 0.0323 |
| D(LPOP)            | 16.48436***  | 5.42648    | 3.037763    | 0.0032 |
| D(LPOP(-1))        | -9.433976    | 4.845771   | -1.946847   | 0.0995 |
| ECT <sub>t-1</sub> | -0.714693*** | 0.040444   | -17.67118   | 0.0031 |

\*\* and \*\*\* indicating a significant level of 5 and 1%, respectively.

Source: By authors from research data.

## Appendix C: Long run regression

Dependent variable: D (LGFCF)

Method: Stepwise regression

Date: 04/22/24 Time: 12:36

Sample (adjusted): 1987 2020

Included observations: 34 after adjustments

Number of always included regressors: 10

Number of search regressors: 18

Selection method: Uni-directional

Stopping criterion:  $p$ -value = 0.05

| Variable                   | Coefficient | Std. error            | t-Statistic | Prob.*    |
|----------------------------|-------------|-----------------------|-------------|-----------|
| C                          | 15.60299    | 3.444799              | 4.529434    | 0.0002    |
| LGFCF(−1)                  | −0.688240   | 0.134072              | −5.133345   | 0.0001    |
| LED_POS(−1)                | −1.125648   | 0.297123              | −3.788488   | 0.0012    |
| LED_NEG(−1)                | 0.123718    | 0.068556              | 1.804626    | 0.0862    |
| LEXP(−1)                   | 0.262656    | 0.171552              | 1.531054    | 0.1414    |
| LINV(−1)                   | 0.364636    | 0.106287              | 3.430659    | 0.0026    |
| LEXR(−1)                   | −1.319148   | 0.336775              | −3.917007   | 0.0009    |
| LINF(−1)                   | −0.097045   | 0.051314              | −1.891200   | 0.0732    |
| LTRADE(−1)                 | −0.668552   | 0.167288              | −3.996409   | 0.0007    |
| LPOP(−1)                   | 4.417523    | 1.206294              | 3.662062    | 0.0015    |
| D(LINV)                    | 0.391993    | 0.072991              | 5.370418    | 0.0000    |
| D(LTRADE(−1))              | 0.374900    | 0.138346              | 2.709883    | 0.0135    |
| D(LTRADE)                  | −0.390617   | 0.156158              | −2.501418   | 0.0212    |
| D(LGFCF(−3))               | 0.240855    | 0.098549              | 2.444022    | 0.0239    |
| <i>R</i> -squared          | 0.852335    | Mean dependent var    |             | 0.018877  |
| Adjusted <i>R</i> -squared | 0.756354    | S.D. dependent var    |             | 0.211202  |
| S.E. of regression         | 0.104251    | Akaike info criterion |             | −1.391137 |
| Sum squared resid          | 0.217364    | Schwarz criterion     |             | −0.762636 |
| Log likelihood             | 37.64933    | Hannan-Quinn criter.  |             | −1.176800 |
| <i>F</i> -statistic        | 8.880164    | Durbin-Watson stat    |             | 1.481045  |
| Prob( <i>F</i> -statistic) | 0.000011    |                       |             |           |
| Selection summary          |             |                       |             |           |
| Added D(LINV)              |             |                       |             |           |
| Added D(LTRADE(−1))        |             |                       |             |           |
| Added D(LTRADE)            |             |                       |             |           |
| Added D(LGFCF(−1))         |             |                       |             |           |

\**p*-Values and subsequent tests do not account for stepwise selection.

Source: By authors from research data.