PUBLIC DEBT AND DRIVERS OF ECONOMIC GROWTH IN GHANA: EMPIRICAL ANALYSIS FROM 1970 TO 2023

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# Abstract

This study looks at how different factors impact economic growth in Ghana from 1970 to 2023, using both ARDL (Autoregressive Distributed Lag) and HAC (Heteroskedasticity and Autocorrelation Consistent) models. The use of both models provides a more reliable and accurate analysis by capturing long-term relationships (ARDL) and correcting for serial correlation issues (HAC).

Key findings include that a growing population negatively affects economic growth. The study also shows that government expenditure and government debt have negative impacts on economic growth. Higher government spending, if not targeted effectively, may divert resources from more productive investments. Similarly, high debt burdens reduce fiscal flexibility and hinder growth. Life expectancy didn’t show consistent results across both models, suggesting it may not always lead to higher productivity if an aging population becomes more dependent.

Remittances, or money sent back by Ghanaians abroad, are found to have a negative impact on growth. This could be because people may rely too much on remittances rather than investing in local businesses or increasing productivity. Lastly, foreign direct investment (FDI) had no significant effect on GDP growth, likely due to domestic factors like inadequate infrastructure and skilled labor.

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# Introduction

Ghana after independence in 1957 was one of the most prosperous countries in Africa, highly endowed with natural resources mainly in cocoa and gold. The country experienced steady growth rate from the 1960s to the 70s where it started recording negative growth due to the fall in global commodity prices as against a sharp increase in oil prices (Killick, 2010).

The period of the early 70s also experienced an irregular political atmosphere leading to gross level of mismanagement, high inflation, corruption, and decline in the cocoa sector, which created a high cost of living and a significant decline in the living standards.

The government after the 1970s initiated economic reforms and policies that aimed at opening up the economy and helping cut the burdens of citizens amid harsh economic conditions brought by the erratic political atmosphere over the years. These required the government to invest hugely in areas such as infrastructure, health, education, social welfare among several areas of great concern to the economy. To achieve these goals, the government had to rely on two main sources in raising the needed funding, which are government revenue through taxes, fees and fines and through borrowing to finance the deficit budgeting. As Owusu-Nantwi and Erickson (2016) posited, revenue from taxation is usually insufficient to support government investment expenditures causing high budget deficits. Budget deficit is expected when the planned government expenditures exceed that of government revenue. This can be curtailed by government raising taxes, increasing fees and fines or by borrowing from the banking system or through international capital markets. The latter is usually preferred across the world as increasing taxes leads to higher prices which are mostly passed on to consumers, which eventually leads to inflation.

Increasing budget deficits over the years have placed significant pressure on governments and policymakers to find effective ways to finance and reduce them, but this has not seen any significant success. It has been suggested by Rosen and Gayer (2008), that public finance offers three primary methods for financing deficits: increasing taxes, implementing user fees, and borrowing through debt. Developing nations, constrained by weak tax systems and low-income levels, often choose debt as the most viable option for financing government budgets. As a result, public debt plays an especially significant role in these countries, (Owusu-Nantwi and Erickson, 2016).

Since gaining independence, Ghana has sought assistance from the International Monetary Fund (IMF) for an economic recovery program for a record 17 times (Abotebuno Akolgo, 2023). Ghana’s history with the IMF reflects the country’s struggle to balance economic growth with fiscal discipline, having experienced periods of economic growth, punctuated by fiscal crises that have led to cycles of external borrowing and subsequent debt restructuring efforts. While IMF programs have helped stabilize the economy during crises, achieving sustained growth and avoiding repeated debt accumulation remains a challenge. Despite these interventions, the debt-to-GDP ratio has continued to climb, increasing by approximately 80%, with the national debt rising from US$20.1 billion to US$36.2 billion between 2015 and 2021 (Abotebuno Akolgo, 2023).

Borrowing has therefore become an effective tool that helps in bridging the gap between government revenue and government expenditure without cutting spending or raising taxes (Musgrave et al, 1989). African Development Bank (AfDB) reported in February 2022 that twenty-three Africa countries are in debt due to the persistent deficit financing and if this is not put in checks, may lead to a distress level. The persistent increase in debt level and its associated cost of servicing is something policy makers have taken into great concern.

Borrowing to finance budget deficit usually becomes a concern when the borrowed amount is not invested in sectors of the economy that yields returns to be able to pay back the borrowed sum within the stipulated period of the loan. These productive sectors are income generating sectors that can cater for the immediate servicing of the borrowed fund and impending payment of the principal at the end of the loan term. Siddique et al., (2016), explained that, if borrowed amount is not invested in productive areas of the economy to generate income, the country will not be able to settle the loan when due, and with time, causes debt accumulation which becomes a constraint on economic growth and achieving economic welfare.

The economic policy of Ghana is to pursue prudent financial and economic management which aims at improving the welfare and general economic condition of citizens in areas of health, security, education, social services, infrastructure and the promotion of human rights through effective public institutions (Owusu-Nantwi and Erickson, 2016). Meeting these needs requires the government to go beyond the internal revenue generating stream, which is always insufficient necessitating borrowing from both local and international financial markets. The country’s debt accumulation, and its inability to honor debt servicing in recent time made it enter another agreement with the IMF to seek financial bailout and embark on debt exchange program, postponing mature debt instruments to future dates and renegotiating with international communities on loan terms. As of January 2024, Ghana’s total debt stood at $53.1 billion representing equivalent to 70.6 percent of GDP (Ministry of Finance, Ghana, 2024). The level of borrowing and debt accumulation should have transformed the growth path of the country to help payback the borrowed funds. This is not the case of Ghana, the debt accumulation has rather led to high taxes, higher interest rates and higher inflation. This relationship between public debt and economic growth should therefore be taken into consideration by all governments across the globe. Eberhardt and Presbitero (2015), explained that the relationship between public debt and economic growth has been a major research path by those in academia and policy think tanks.

Several studies have been conducted in recent years emphasizing the importance of public debt on economic growth. Researchers like Bakar and Hassan (2008), Owusu-Nantwi and Erickson (2016) and Umutlu et al. (2011) asserted that debt has a significant impact on economic growth. Others like Doğan and Bilgili, (2014) Eberhardt and Presbitero (2015), Egert (2015) and Kourtellos et al. (2015), studied and concluded that the level of a country’s debt has an inverse relationship with economic growth.

Owusu-Nantwi and Erickson (2016), conducted similar research on Ghana using government consumption expenditure, investment, inflation, population growth and sum of exports and imports. The findings reveled a positive significant relationship between public debt and economic growth of Ghana. Emmanuel et al, (2018) also alluded to the study conducted by Owusu-Nantwi and Erickson (2016). Abigail D. (2023) studied public debt and economic growth on Ghana using variables like interest rate, exchange rate, current account balance and money growth and concluded that some macroeconomics variables respond positively to public debt whiles others tend to be negative.

There is limited evidence of study on public debt and economic growth in Ghana that has captured the effects of savings (Investment), remittances, and life expectancy as variables. This study, in addition to some of the previously studied variables, review the study conducted by Owusu-Nantwi and Erickson (2016) on public debt and economic growth of Ghana, and tends to fill the gaps and propose recommendations on efficient debt levels that may sustain economic growth. Generally, this study seeks to empirically assess the impact of public debt and other macroeconomic variables on economic growth in Ghana from 1970 to 2023, examining both short-term and long-term effects, and determining the threshold beyond which public debt begins to negatively influence economic growth.

# 2. Literature Review

This section will look at the theories connecting the variables of study for computation and analysis. Significant part of Ghana’s economic history has been the period of debt accumulation and debt sustainability. This rate of debt accumulation has no clear evidence of translating to the desirable pattern of sustained growth over the period. Several studies have concluded on the effect of public debt on economic growth of Ghana using varied economic models and estimations techniques some of which outlined in this chapter.

## 2.1 Classical and Neoclassical Perspectives

Classical economic theory cautiously considers the benefits of public debt as it has the potency to harm the long-term economic growth of a country. As argued by David Ricardo through *Ricardian Equivalence*, cited in Sturn, R. (2015), that government borrowing only postpones the present burden of tax to the future date, and when consumer anticipate the impending taxation, they cut down on consumption expenditure and this slows down the economy. Classical economists believe that increase in public borrowing ultimately brings the burden of debt servicing to consumers through taxation.

Neoclassical economists alluded to this uncertainty, suggesting that increasing levels of public debt will drive out private investment (crowding out) which also affects growth, Woodford, M. (1990). The *crowding-out effect* occurs when the government competes with the private sector for public funds. With this, interest rates go up which makes it expensive for firms and businesses to borrow for investment. In effect, increasing government borrowing causes higher cost of capital, low investment from the private sector, and low economic growth.

## 2.2 Keynesian Perspective

Opposing the classical views, Keynesian economics advances that under certain economic circumstances like economic downturn, increasing the level of public debt can stimulate growth. John Maynard Keynes (1997) explained that in a period of recession, government expenditure could be financed by debt which will in turn stimulate demand for goods and services thereby reviving the economy in the short run. This suggests that in the short run, public debt can be used as an instrument for short run growth provided it is targeted at productive areas that trigger several sectors of the economy. According to Keynesian theory, Ghana with a history of fluctuation growth can strategically use borrowing to stabilize the economy by investing in productive and income generating areas to boost growth and productivity in the long run.

## 2.3 Debt Overhang Theory

The *debt overhang* hypothesis, introduced by Krugman (1988) and Sachs (1989), describes a situation where a country has a huge debt burden preventing it from taking additional debt to finance developmental projects. In the context of Ghana, there exists this theoretical framework indicating that when a country’s debt relative to its GDP becomes substantial, it can reach a point where the burden of repayment hampers both local and foreign investment. Investors may worry that future profits will be heavily taxed to service the debt, resulting in a slowdown of economic growth. This theory suggests that surpassing a specific threshold of public debt can have adverse effects on economic development

## 2.4 Endogenous Growth Theory

Romer (1986) and Lucas (1988) proposed the endogenous growth model, which places emphasis on human capital development, technology, and innovation to stimulate long-term growth. For them, public debt only becomes relevant when it is invested in growth drivers in areas like education, infrastructure, health, and technology. These are the very critical factors to consider when borrowing. As in Ghana, education and infrastructure are critical elements in achieving sustainable growth and endogenous model suggests that the efficiency in using public debt has a direct positive impact on economic growth.

## 2.5 Empirical Review on the Impact of Public Debt and Economic Growth in Ghana

### 2.5.1 Public Debt and Economic Growth: An Overview

Over the past few decades, Ghana has experienced a consistent increase in its public debt. This rise has been driven by a combination of external borrowing (from international lenders and financial institutions) and domestic borrowing (within the country). In May 2024, Ghana’s debt has increased to GH¢658.6 billion, representing 62.7% of the country's GDP. This increase was because of interest rate accumulation on existing loans and depreciation of the Ghana cedi against the US dollar. Increasing level of debt to GDP poses a risk to economic stability even in the short run. Managing debt has been a difficult job for several countries including Ghana. Even though borrowing can help fund developmental projects and programs for a country, there should be limitation to that as when it reaches a certain parameter against the country’s overall production capacity, it creates a hostile economic atmosphere.

### 2.5.2 Empirical Studies on public debt and economic growth

Empirical studies on public debt and economic growth have produced varied results, mostly depending on the production capacity of the country, debt composition, strength of currency, economic structure, interest rate and inflation rate among several other economic variables.

Reinhart and Rogoff, (2010) studied about growth in a time of debt using a historical data of 44 countries over 200 years period and concluded that when public debt goes beyond 90% to GDP of a country, the country will experience negative growth because economic activities will go down as compared to countries that are able to manage their debts at a minimal level. Cecchetti, et al (2011), researched on the real effects of debt using panel data from advanced economies. The study concluded that there is a nonlinear relationship between debt and growth. That debt has a maximum point of stimulating growth beyond which resources for development will be channel to service it which brings the country back to its previous growth pattern. Eberhardt, et al (2015), on public debt and growth using panel cointegration methods and accounted for country heterogeneity to assess the debt-growth relationship concluded that the impact of debt on growth depends on the composition of debt (domestic vs. external) and institutional factors. Countries with stronger institutions can handle higher debt levels without negatively affecting growth as much.

Adusei (2013) conducted a study to examine the relationship between public debt and economic growth in Ghana using data from 1970 to 2010. The results suggest that there is a negative relationship between public debt and economic growth, especially when the debt-to-GDP ratio surpasses a critical threshold of 70%. Adusei argues that high levels of debt crowd out private investment and reduce public sector efficiency due to high interest payments, leading to slower economic growth. Owusu-Nantwi and Erickson, (2016) investigated the impact of both domestic and external public debt on economic growth in Ghana between 1980 and 2015. Their findings suggest that external debt has a more detrimental effect on growth compared to domestic debt. They attribute this to the fact that external debt often comes with strict repayment conditions and foreign currency risk, which can undermine growth prospects. Conversely, domestic debt, particularly when used to finance infrastructure, can have an insignificantly positive impact on growth. Asafo, S. et al (2019), using co-integration and error correction methodology studied the impact of external debt on economic growth in Ghana in a period of 47 years and concluded that there is always a crowding out effect in the short and long run when external debt exceeds some threshold. The study also reported that debt overhang exists in the short term when borrowing is used to stimulate growth. A more recent study on public debt and economic growth in Ghana by Abigail D. (2023), reported that inflation and interest rates will negatively be impacted when there is excessive borrowing from external sources, and this will end up affecting the strength of Ghana cedi in the long run.

## 2.6 External and Domestic Debt Dynamics

Empirical studies evidence the need to separate external debt from internal debt. Notable ones include Frimpong and Oteng-Abayie (2006), they determined from the study that external debt hold more threat to economic growth of Ghana as compared to internal debt. They explained that external debt usually comes with strict conditionalities and poses the risk of hampering the local currency. Unlike external debt, the domestic debt poses a minimal risk of affecting the local currency and has minimal to no attachment which can easily be used to finance local projects.

## 2.7 Debt Sustainability and Growth

Ghana's debt sustainability is an essential concern, as highlighted by the International Monetary Fund (IMF) and the World Bank. Empirical studies have shown, Reinhart and Rogoff, (2010), Adusei (2013), and Asafo, S. et al (2019), that when debt exceeds sustainable levels, the country becomes vulnerable to shocks such as currency depreciation and rising interest rates, which further impede growth, Abigail D. (2023). An IMF report (2020) noted that Ghana's rising debt service burden (over 40% of government revenue) crowds out expenditure on critical social services and infrastructure, limiting the country’s ability to achieve robust economic growth.

2.8 Gross Domestic Product (Gr) and Economic Growth

GDP is the primary indicator of a country's economic performance. In Ghana, fluctuations in GDP reflect changes in overall economic productivity and wealth creation. Studies such as those by Aryeetey & Fosu (2003) and Boakye & Oteng-Abayie (2011) emphasize that GDP growth correlates positively with improved living standards, poverty reduction, and employment creation. Boamah et al. (2019)however explained that structural weakness, unproductive agriculture sector and unimproved manufacturing avenues has impeded the sustained growth of gdp.

2.9 Inflation (Infr) and Economic Growth

Inflation is a key macroeconomic challenge in Ghana. High inflation can distort pricing mechanisms, reduce consumer purchasing power, and erode business confidence. It also affects the interest rate in the financial market that prevents businesses from securing loan facility to expand their businesses. Studies like that of Frimpong & Oteng-Abayie (2006) demonstrate the inverse relationship exists between inflation and economic growth. Higher inflation rate does not only affect consumption which drives growth, but also affects the strength of the local currency which tends to be volatile.

2.10 Remittances (Rem) and Economic Growth

Remittances are monies sent from abroad to home countries usually in foreign dominated currencies. It contributes directly to household income and consumption. It presents a huge foreign exchange inflow for Ghana. As reported in the daily graphic ([Graphic Online](https://www.graphic.com.gh/daily-graphic-editorials/ghana-news-lets-leverage-remittances-for-economic-growth.html), Aug 22, 2024), remittances account for about 6% of Ghana's GDP, with inflows exceeding $4.8 billion in 2023. It helps alleviate household poverty by providing regular support to families across the country. Putting in relevant measures to support such inflows will go a long way in helping achieve economic growth. Research by Fayissa and Nsiah (2010) also supports the argument that remittances contribute to economic growth in Sub-Saharan Africa, where formal financial systems are often inadequate. Remittances help ease liquidity constraints faced by households, leading to an increase in investments in education, housing, and small businesses, thereby contributing to overall economic growth.

While many studies highlight the positive role of remittances, some scholars have raised concerns about the potential negative impact of remittances on long-term economic growth. Chami, Fullenkamp, and Jahjah (2003) argued that remittances might create a “moral hazard” problem, where recipients reduce their labor market participation and rely on remittances for their livelihood. This dependency can hinder economic growth, as it reduces the labor force's contribution to domestic production.

2.11 Foreign Direct Investment (fdi) and Economic Growth

Foreign Direct Investment (fdi) is a vital catalyst for Ghana's economic growth, contributing significantly through capital influx, employment generation, and the introduction of new technologies. FDI has been a vital source of economic growth for Ghana, bringing in capital investment, technology and management knowledge needed for economic growth. (Antwi, et al, 2013). In 2022, the country secured $1.47 billion in FDI, though this reflected a 39% drop compared to the previous year. Key investments are largely focused on sectors such as oil, gas, mining, and agriculture, all of which have consistently fueled the country's GDP expansion​ (Obeng-Amponsah, et al, 2023).

2.12 Government Expenditure (Ge) and Economic Growth

Several studies have examined the relationship between government expenditure and economic growth in Ghana. For instance, Mensah, Ofori, and Boateng (2019) found that increased government spending on infrastructure and social services positively impacts GDP growth. However, inefficiencies and misallocation of funds can diminish these effects. Asamoah (2020) argues that excessive government spending without corresponding revenue growth can lead to deficits and economic instability, hampering long-term growth. Government spending stimulates aggregate demand, especially in times of economic downturn. By increasing public investment or consumption, the government can create jobs and inject capital into the economy, leading to higher output and employment.

1. Life expectancy (le) and Economic Growth

Life expectancy has a significant impact on the economic growth of every country in the world. As people live longer, they tend to provide more experience in the labor market which increases productivity in the long run. People living longer have the incentive to save more against their retirement which is mobilized domestically for investment. Several studies have been conducted on life expectancy and economic growth which have produced mixed results across countries. Lorentzen, McMillan, and Wacziarg (2008), argued that low life expectancy creates an environment where short-term survival trumps long-term economic planning. People who have no hope of living longer do not plan for the future since they will ultimately die in a short period of time. This not only affects their individual future plans, also affect the economy in general as less is committed on future occurrences. Barro (1996), cross-country empirical analysis finds that life expectancy is a key determinant of economic growth. A 5-year increase in life expectancy is associated with a 0.3 to 0.5 percentage point increase in annual per capita GDP growth. When people live longer, they tend to spend more on consumption which also improves the general economic wellbeing of a country over time.

3. Population (Pop) and Economic Growth

Population has a significant impact on economic growth in a mixed relationship. A growing population can expand the labor force, increasing the productive capacity of an economy. More people often lead to greater consumption and demand for goods and services, driving economic activity and investment opportunities. Osei (2017) found that moderate population growth can enhance labor supply and market expansion, boosting economic output. However, if population growth exceeds economic capacity, it can strain resources and infrastructure, negatively affecting growth. Aryeetey and Fosu (2018) emphasize that without adequate investments in human capital and employment opportunities, rapid population growth could hinder economic progress.

# 3. Data

This study employs annual time series data of Ghana from 1970 to 2023 for the analysis. From the literature review, remittances and life expectancy have been added to the previous study conducted by Owusu-Nantwi and Erickson (2016) on the same study area. This fills the research gap of his study as such important variables cannot be overlooked by previous studies on economic growth in Ghana.

In all, seven macroeconomics variables are used to access their influences on economic growth. These are Gdp growth rate as the measure of economic growth, inflation rate, remittances, government expenditure, population, government debt, foreign direct investment and life expectancy. These variables are shown in table 1 below with their descriptive statistics. Enders**,** (2014) suggested that 30 to 50 observations are usually sufficient in time series data that involves macroeconomics variables. The study therefore uses eight variables in the period of 54 years.

### Table 1: Data Description

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variables | | Definition | Mean | SD |
| lny | Logged annual Real GDP growth | | 2.636 | .236 |  |
| Inx1 | Logged population Growth rate in % | | 3.846 | 4.743 |  |
| lnx2 | Logged inflation as measured by the CPI in % change | | .689 | 1.134 |  |
| lnx3 | Logged government expenditure in US dollars | | 2.351 | .215 |  |
| lnx4 | Logged government debt in US dollars | | 21.988 | 1.08 |  |
| lnx5 | Logged average life expectancy | | 53.598 | 4.702 |  |
| lnx6 | Logged remittances in US dollars | | 23.619 | 37.554 |  |
| lnx7 | Logged foreign direct investment as in US dollars | | 2.153 | 2.709 |  |

n= 44

## 3.1 Dividing the Sample

To be able to forecast the effect of the independent variables on economic growth of Ghana, the data set was divided into in-sample (training set) and out-of-sample set. 80 percent of the sample size from 1970 to 2013 were chosen as the in-sample dataset and from 2014 to 2023 dataset serves as the out-sample, which 20 percent of the total data set.

## 3.2 Stationarity Test

To test for stationarity, Augmented Dickey-Fuller (1979) unit root test was conducted. This is necessary since non-stationarity exists in most time series data and if not well checked, the regression results may be spurious, Owusu-Nantwi and Erickson (2016). The unit root test helps the study know how the variables are integrated and their stationarity. Table 2 shows the ADF testing and their stationarities.

### Table 2: ADF Test

|  |  |  |  |
| --- | --- | --- | --- |
| Unit Root ADF Test | p-value |  | Decision |
| H0：Gdp growth rate has unit root | 0.5931 |  | Fail to reject *H*0 |
| H0: Population has unit root | 0.000 |  | Reject *H*0 |
| H0：Inflation rate has unit root | 0.1852 |  | Fail to reject H0 |
| H0：Government expenditure has unit root | 0.0937 |  | Fail to reject *H*0 |
| H0：Government debt has unit root | 0.0088 |  | Reject H0 |
| H0：Life expectancy has unit root | 0.7436 |  | Fail to reject *H*0 |
| H0：Remittances has unit root | 0.2257 |  | Fail to reject *H*0 |
| H0:  Foreign direct investment has unit root | 0.1640 |  | Fail to reject H0 |

Table 2 shows that only Population growth and government debt are stationary at a level. The study therefore employs cointegration and ARDL model for estimation since the variables have mixed stationarities, and most of them only become stationary after their first difference. This is then corrected to avoid running spurious regression and ensures the long run relationships that exist among the variables, and also enhance the accuracy of the results and prediction.

## 3.3 Model

The study uses the Solow growth model to explore the relationship between public debt and economic growth. Several studies have been carried out in this area which mostly overlooks the significance of remittances from abroad and the life expectancy of the people of Ghana. The study therefore incorporates remittances and life expectancy to the Solow model and explore their effects on economic growth in Ghana, alongside other variables reviewed.

*lny,t = β0 +β1\*lnx1t+ β2\*lnx2t + β3\*Inx3t + β4\*lnx4t +β5\*lnx5t + β6\*lnx6t + β7\*lnx7t + ξ**t*

Where lny, lnx1, lnx2, lnx3, lnx4, lnx5, lnx6, and lnx7 are the variables of study as described in table 1, the error term (*ξ*), t is the time period from 1970 to 2023, *β0*  is the constant term and the *β* are the coefficients of the independent variables listed above.

This helps in removing the trend that may exist in the variables. Table 4 shows the preliminary OLS estimation using the in-sample data set from 1970 to 2013 to guide in selection of variables that fits the model.

## 3.4 Johansen Cointegration Test

The Johansen co-integration test was conducted for all the variables with unit root at their levels using the in-sample data set and a lag length of 1, based on AIC. The test results show that at least one variable in cointegrating based on the rank (number of cointegrating relationships) against the Trace statistic and the Max-Eigenvalue statistic, compared with the 5% critical values. With this, the null hypothesis is rejected which indicates that there is a long-run equilibrium relationship between the variables which allows to capture short-term dynamics while preserving the long-run relationship. This result is shown in table 4 which indicates that there is at least one variable that is cointegrated at levels with r > 0 at trace statistics value greater than the 5% critical values at ranks 0 and 1 with the null hypothesis being rejected at these levels.

## 3.5 Bounds test

The Bound test was conducted to determine the short run and the long run relationship between the variables, especially when these variables are of mixed stationarities and ARDL model is used as the estimation. This approach checks if long-run relationships hold regardless of which variable is dependent, Pesaran, et al (2001). With this, Population (lnx1) was used as the dependent variable. When the F-statistic is greater than the upper Bound, then cointegration exist among the variables and you reject the null hypothesis and if the F-statistic is less than the lower Bound, you fail to reject the null hypothesis, that, there is no long run relationship among the variables. Using the Kripfganz and Schneider (2020) approach, the null hypothesis was rejected at 10% and 5% critical values indicating the existence of long run relationships with F-statistics of 5.422 and absolute t statistics of 5.722.

## 3.6 Model selection

In selecting the appropriate model, the golden rule is variables that are not fit for purpose, based on their t statistics which is less than absolute 2 are dropped. That is, variables that are not statistically significant to the model are assessed using the F statistics to determine their combine effects on the model when there are more than one of such variables. Two parameters are used here, the restricted model and the unrestricted model. The unrestricted model is the general model used in the preliminary OLS estimation and restricted model is the model that excludes variables which are statistically insignificant, that is, their absolute t values are less than 2.

From the preliminary OLS estimation, it was identified that lnx2 (Inflation), lnx3 (government expenditure) and lnx7 (Foreign direct investment) are not statistically significant to the model but were noticed to be statistically significant in the long run relationship with other variables. Government expenditure drives economic growth while excessive expenditure by the government also leads to inflation which affects the economic growth. This relationship is confirmed by the cointegration test conducted in table 4.

Wooldridge, (2010) emphasizes the importance of model specification and the role of theoretically relevant variables, even if they are not statistically significant in the short run. Also to avoid distortioning the relationship between the dependent variable and the independent variables that will affect the model specification causing omitted variable bias, these two variables are included in the model. Greene, (2018) explained omitted variable bias and its implications for regression models, emphasizing the importance of including all relevant variables to obtain unbiased estimates. Inflation and government expenditure have a theoretical long run relationship that needs not to be underestimated. The paper argues that such variables are essential for accurately modeling the dynamics between variables over the long run. The model is therefore specified as the original one.

lny = β0 +β1\*lnx1t+ β2\*lnx2t + β3\*Inx3t + β4\*lnx4t +β5\*lnx5t + β6\*lnx6t + β7\*lnx7t + ξt

# 5. Residual Diagnostics

To ensure the robustness and reliability of the model estimates and inferences, it is essential to examine the difference between the observed values and the model’s predicted value. With this, the study tests for the models’ linearity of variables, homoscedasticity, multicollinearity and autocorrelation.

## 5.1 Linearity

The study conducted a linearity test using the Shapiro-Wilk W test to assess the normality of the data. The results indicated a p-value greater than 0.05, leading to the failure to reject the null hypothesis. This outcome suggests that the data follow a normal distribution, supporting the assumption of normality required for further analysis. The results is shown in table 5 and in figure 1 in the appendix.

## 5.2 Multicollinearity

The study tested multicollinearity using the Variance Inflation Factor (VIF). The results showed a mean VIF value of 3.51, indicating multicollinearity is not an issue in the model. According to the standard rule, a VIF value greater than 10 suggests the presence of multicollinearity. Since the mean VIF and that of all the variables are well below this threshold, the model's independent variables are not excessively correlated, ensuring reliable coefficient estimates.

## 5.3 Heteroskedasticity

To ensure the regression results were reliable, heteroscedasticity was tested. Residual plots indicated a consistent variance across the data points as shown in figure 2 in appendix. This was further confirmed using the Goldfeld-Quandt test, which yielded a p-value of 0.4091. Since the p-value is above 0.05, we failed to reject the null hypothesis of constant variance, confirming that the data exhibits homoscedasticity.

## 5.4 Autocorrelation

The presence of autocorrelation in the variables was confirmed through both the Durbin-Watson and Breusch-Godfrey tests. The Durbin-Watson statistic, which ranges from 0 to 4, indicates no autocorrelation at a value of 2, positive autocorrelation for values below 2, and negative autocorrelation for values above 2. The initial Durbin-Watson test is 0. 7990, signaling the presence of positive serial correlation. This finding is further supported by the Breusch-Godfrey test, which produced a p-value of less than 0.05, leading to the rejection of the null hypothesis of no serial correlation, as shown in Table 7. This is indicative that serial correlation exists in the data and will be corrected using the HAC estimate.

# 6. Estimation

This study uses the Autoregressive Distributed Lag (ARDL) model to explore the relationship between the dependent and independent variables. The ARDL model is particularly useful because it can handle data with mixed levels of integration (I(0) and I(1)) and estimates both short-run and long-run relationships in one framework, making it flexible and efficient for analyzing cointegration.

To ensure accurate results, heteroskedasticity- and autocorrelation-consistent (HAC) standard errors were used for the ARDL model. These adjustments address potential issues like uneven variance (heteroskedasticity) and serial correlation in the residuals which were initially detected through the Breusch-Godfrey test, which could otherwise distort estimates and significance levels making them less precise. Using HAC standard errors makes the results more reliable for hypothesis testing (Newey, Et al, 1987). Pesaran, et al (2001), in their paper highlights the importance of adjusting standard errors to obtain more reliable t-statistics and p-values, particularly when using ARDL models for time series data. With this, the coefficients obtained from the HAC estimates will be more appropriate in estimating alongside the ARDL estimates, ensuring more reliable inference in empirical applications.

# 7. Empirical Results

### Table 8: Estimation Results

|  |  |  |  |
| --- | --- | --- | --- |
| Dependent variable =  GDP growth rate (lny) | PRELIMINARY OLS | ARDL | ARDL (HAC) |
| Coef. | Coef. | Coef. |
| Logged Gdp growth rate (lny)  L1 |  | 0.731  (0.099) | 0.731\*\*\*  (0.061) |
| Logged Population (lnx1) | -.0133\*\*  (.006) | -0.006  (0.004) | -.013  (.005) |
| Logged Inflation (lnx2) | .0054  (.033) | 0.051\*\*\*  (0.022) | .051\*\*  (.021) |
| Logged Government expenditure (lnx3) | -.071  (.054) | -0.101\*\*  (0.041) | -.103\*\*  (.048) |
| Logged Government debt (lnx4)  SR  LR | -.279\*\*  (.124) | -0.278\*\*  (0.107)  .352\*\*  (.107) | -.278\*\*\*  (.1)  .352\*\*  (.165) |
| Logged Life expectancy (lnx5) | -1.829\*\*  (.897) | 0.037  (0.692) | 0.037  (0.627) |
| Logged Remittances (lnx6) | -.142\*\*  (.0053) | -0.041  (0.036) | -.041  (.023) |
| Logged Foreign Direct Investments (lnx7) | -.0176  (.014) | -0.018  (0.010) | -.019  (.009) |
| Constant | 9.357\*\*\*  (3.14) | 0.449  (2.443) | 9.357  3.206 |
| Adjusted R-squared  Observations | 0.5857  44 | 0.8432  44 | 44 |

The study uses both ARDL and HAC models for the estimation. Using ARDL and HAC models together provides a more complete and reliable analysis, helping to ensure that the results are accurate and trustworthy. The ARDL helps capture the long run relationship among the variables while the HAC performs error corrections from the serial correlation that was detected in Table 7. After the error corrections, some observations were made; robust standard errors were noticed, population, remittances and life expectancy which were statistically insignificant in the OLS model became statistically insignificant in the ARDL model. These give credence to HAC for giving accurate and more reliable results.

From the estimation, population had negative coefficient in the model which was statistically not significant. A larger population can put pressure on resources and limit economic progress, resulting in slower economic growth. A percentage increase in population growth will decrease economic growth by 0.013 percent. This reflects concerns raised by Malthus, particularly in developing countries. The negative relationship between population growth and GDP growth seen in the estimates suggests that as the population grows, its impact on economic output becomes weaker. A growing population can lead to a higher dependency ratio, meaning there are more people relying on the working-age population, which can put a strain on resources and slow down economic growth. This finding is consistent with Barro (1996), who explains that demographic changes, especially population growth, can affect economic growth. He highlights how larger populations may stress economic resources, particularly if productivity doesn't increase at the same pace. This finding however contradicts with that of Owusu-Nantwi and Erickson (2016), who undertook similar studies in Ghana and found that population growth has positive significant effect on economic growth.

With inflation 0f 0.052 which is statistically significant, a percentage increase in inflation will increase economic growth by 0.052 percent. This means moderate inflation can be a sign of strong demand for economic activity, indicating a healthy economy. However, when inflation becomes excessive, it can often have a negative impact on growth (Fisher, 1930). In this case, inflation has a small but positive effect on GDP growth. In developing economies, inflation often reflects rising demand, which can drive economic expansion. This aligns with the work of Owusu-Nantwi and Erickson (2016), Narnor (2023) and Boakye and Oteng-Abayie (2011), who examine how inflation impacts small economies. They argue that inflation can have positive short-term effects on growth, primarily because it often results from increased demand within the economy, in which firms mostly respond to the demand by increasing output, which ends up driving the economy up.

On government expenditure, the study revealed that there is an inverse relationship between government expenditure and economic growth. A percentage increase in government expenditure will have economic growth decline by 0.01 percent. Essentially, when the government spends more, it could divert funds away from more productive investments, leaving less for the private sector to grow the economy. Excessive government spending can also create inflation which ends up reducing the real purchasing power. This result deviates from economic theory as government expenditure is a significant contributor to economic growth. The situation might be different from Ghana where perhaps government spending is not geared towards investment avenues that are able to yield positive results. More to this is the introduction of free shs that has taken the greatest part of government expenditure over the years. This can also be possible in situations where government expenditure is funded by internal borrowing that creates a challenge for private investor when it comes to competing with the government for funding. This is supported by Asamoah (2020), who points out that government spending can harm growth if it's not properly targeted or if it's poorly funded. In such cases, the economy might suffer because resources are not being used in the most effective way.

The results show a negative relationship between government debt and economic growth in the short run with the coefficient of -.278 being statistically significant. This suggests that higher levels of government debt may impede economic growth, likely due to the increased burden of debt servicing and a reduction in fiscal flexibility. In cases where this debt is secured from within the country, it creates a crowding out effect which affects private investments which ends up affecting the economy in negative ways, in the short run. This becomes more profound when government spend more than the taxes it takes from the public to support its budget; decline in exported commodity prices on the international market which keeps budget imbalance due to low revenue expectations and unexpected shocks on economic growth. These push the government to rely on borrowing to support its budget, and the excess of this affects the economy negatively. In the long run, the study shows that government debt has positive effects on economic growth as a percentage increase in government debt will increase GDP growth rate by 0.369 percent. When the borrowed funds are invested in areas with positive returns, it drives the economy to prosperity in the long run and possible, the results clearly shows that in Ghana’s situation. These findings align with the work of Reinhart and Rogoff (2010), who argue that high government debt levels can constrain future economic growth by diverting resources toward debt payments rather than productive investments. Furthermore, this result is consistent with Asafo and Matuka (2019), who also find that external debt negatively affects economic growth in Ghana. In addition, the findings are in line with Narnor (2023), who highlights that, in the Ghanaian context, public debt poses a significant challenge to long-term growth, especially when debt is not effectively utilized to promote productive investments.

The results on life expectancy is statistically insignificant. The significant negative relationship between life expectancy and GDP growth is unexpected because longer life expectancy is typically linked to better health outcomes, which can lead to improved labor productivity. However, this negative result could reflect Ghana’s situation where a longer life expectancy leads to a higher dependency ratio, meaning there are more elderly people who are not actively working. This could potentially slow down economic growth, especially when the savings of the working population help in capital accumulation for further investment in the economy. People living longer without accompanying productivity tends to be a burden on the state as state resources are needed to support such vulnerable individuals who may not have contributed positively to the economy in the past. Lorentzen et al. (2008) discuss how changes in death rates and age structures can influence economic performance. They suggest that a larger proportion of the population being older may reduce growth, as older populations may not contribute as much to the workforce, thus limiting overall economic output. On the other hand, a positive significant life expectancy value indicates that the longer people live, the better for the economy as their contributions over the years help generate economic progress. Here, savings over the period serve as medium through which capital is generated for further investments in the economy. Those who live longer also participate in economic activities, at least until their retirement, and live on their pensions without relying on government support for funds that could be used for further development. A study by Bloom, Canning, and Fink (2014) highlights how longer life expectancy plays a crucial role in driving economic growth, particularly in countries that have undergone significant demographic changes. Longer lives encourage individuals to invest more in education and skills, boosting their productivity and earning potential. This dynamic contributes to higher income levels and overall economic development.

For Ghana, where life expectancy has steadily improved due to better healthcare and living conditions, this principle holds significant promise. As more Ghanaians live longer, they are likely to pursue higher education and specialized skills, enhancing the country’s human capital. This, in turn, supports productivity growth across sectors such as agriculture, services, and industry, helping to reduce poverty and stimulate economic progress.

Remittances (lnx6) show a negative relationship with economic growth in model being statistically insignificant. This negative relationship between remittances and GDP growth indicates that remittances might reduce the incentive for the domestic population to engage in productive work or invest in local businesses. The recipients rely solely on the transfers received from abroad for survival and do not make any productive activities with them. When this happens continuously, then productivity slows down leading to poor economic performance as remittances are mainly for consumption and this will have no meaningful positive effect on the economy. In Ghana, remittances often help wealthier families more than poorer ones. This happens because migrating abroad, where remittances come from, requires resources that only middle or upper-income families can afford. As a result, poorer communities see fewer benefits, and this can increase the gap between the rich and the poor instead of reducing it. Also, when a lot of money flows into the country, it can make the local currency stronger, which makes Ghana's exports more expensive and less competitive in international markets. This could harm key industries like agriculture and manufacturing, which are important for long-term economic growth. The findings confirm that of Perez-Saiz et al., (2019) whose findings indicated that if remittances are mostly used for everyday spending instead of investments in things like infrastructure or education, they won’t help the economy grow in the long term. Large amounts of remittances can also reduce the need for people to work, as they may depend more on money coming from outside the country. This can lead to lower productivity and slower economic growth (Depken et al., 2021).

On foreign direct investment (lnx7) both estimates show a negative, but statistically insignificant, effect of foreign direct investment (FDI) on GDP growth. Normally, FDI is expected to boost growth by bringing in capital and new technologies, but these results suggest that the country may lack the infrastructure or skilled workforce needed to fully benefit from foreign investment. Antwi et al. (2013) explain that in Ghana, local factors such as skill levels and governance can limit the positive effects of FDI on economic growth. Likewise, Asamoah (2020) argues that poor government policies and a lack of human capital can prevent FDI from being used effectively, reducing its potential impact. Boamah (2019) also points out that, without the right institutional setup, FDI may not lead to long-term growth, particularly in smaller economies. These findings suggest that the success of FDI depends largely on the country’s internal conditions.

# 8. Forecasting

The data from 2014 to 2023 was used for forecasting, making up 20 percent of the total dataset. According to Table 9, the ARDL model, after correcting for errors using the HAC method, shows smaller out-of-sample forecast errors compared to the historical constant mean model. Specifically, the ARDL model has lower values for both the root mean squared forecast error (RMSFE) and the root mean absolute forecast error (RMAFE). This suggests that the ARDL model is better at making accurate predictions than the historical constant mean model and has the potential to deliver more reliable forecasts in future analysis. The smaller error values for the ARDL and HAC models indicate stronger predictive performance.

### Table 9: Forecast evaluation

|  |  |  |
| --- | --- | --- |
| Model | RMSFE | RMAFE |
| Historical mean model | 0.5165 | 0.6984 |
| ARDL model | 0.4052 | 0.6157 |

# 9. Conclusion

The study used both ARDL and HAC models to analyze the factors affecting economic growth. By combining these models, the study was able to capture long-term relationships while also correcting for serial correlation, leading to more accurate and reliable results. After correcting for errors, some key findings emerged: variables like population and remittances, which were insignificant in the ARDL model, became significant in the HAC model, while life expectancy lost its significance. Inflation, government expenditure, and government debt remained significant in both models, reinforcing the reliability of the HAC estimates.

The study found that population growth negatively impacts economic growth, likely due to resource strain and an increasing dependency ratio, aligning with Barro’s (1996) argument. However, this contradicted the findings of Owusu-Nantwi and Erickson (2016), who found a positive relationship between population growth and economic growth in Ghana. Inflation, on the other hand, showed a small positive effect on economic growth, suggesting that moderate inflation could signal rising demand, especially in developing economies, consistent with the work of Boakye and Oteng-Abayie (2011).

Government expenditure was found to negatively affect growth, supporting the idea that inefficient spending can crowd out private sector investment, as Asamoah (2020) noted. High government debt also hindered growth, reinforcing Reinhart and Rogoff’s (2010) view that excessive debt limits fiscal flexibility and growth. Life expectancy’s relationship with growth was more complex and contradictory, with a negative effect in the HAC model that might reflect an aging population and a higher dependency ratio, as suggested by Lorentzen et al. (2008).

Remittances were found to have a negative relationship with economic growth, as they may reduce the incentive for productive work and investment, supporting Perez-Saiz et al. (2019) and Depken et al. (2021). Lastly, foreign direct investment (FDI) had an insignificant effect on growth in both models, suggesting that local conditions, such as governance and human capital, may limit its impact, as noted by Antwi et al. (2013) and Asamoah (2020).

The forecasting results showed that the ARDL and HAC models provided more accurate predictions than the historical mean model, further validating their use for future economic analysis.

# APPENDIX

## Table 3: Preliminary OLS estimation

|  |  |
| --- | --- |
| Lny  (Economic Growth) | Coef. |
| Logged Population (lnx1) | -.0133\*\*  (.006) |
| Logged Inflation (lnx2) | .0054  (.033) |
| Logged Government expenditure (lnx3) | -.071  (.054) |
| Logged Government debt (lnx4) | -.279\*\*  (.124) |
| Logged Life expectancy (lnx5) | -1.829\*\*  (.897) |
| Logged Remittances (lnx6) | -.142\*\*  (.0053) |
| Logged Foreign Direct Investments (lnx7) | -.0176  (.014) |
| Constant | 9.357\*\*\*  (3.14) |
| Adjusted R-squared | 0.5857 |
| Observation | 44 |
| \*\*\* p<.01, \*\* p<.05, \* p<.1 | |

## F test

### Table 5: F statistics

|  |  |  |
| --- | --- | --- |
| Variables | P- value | Decision |
| H0: lnx2=lnx3=0 | 0.3060 | Fail to reject H0 |

From table 5, all the variables are jointly not statistically significant to the model since their p values are greater than 0.05 percent, we fail to reject the null hypothesis meaning these variables are not relevant to the model. Eventhough these variables are not relevant, they are however included in the model due to their long term relationship with other variables in the model.

## Table 4: Johansen Cointegration Results

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Rank** | **Null Hypothesis** | **Trace Statistic** | **Critical Value (5%)** | **Conclusion** |
| 0 | r = 0 (no cointegration) | 171.6676 | 156 | Reject Null |
| 1 | r = 0 (no cointegration) | 124.24 | 114.26 | Reject Null |
| 2 | r = 0 (no cointegration) | 78.2984 | 94.15 | Fail to Reject Null |

## Table 5: Shapiro-Wilk W Test for Normal Data

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variable | Obs | W | V | Z | Prob > z |
| Epsilon\_hat | 44 | 0.94995 | 2.130 | 1.60 | 0.05476 |

## Table 6: Multicollinearity test using VIF

|  |  |  |
| --- | --- | --- |
| Variable | VIF | 1/VIF |
| lnx6 | 9.09 | 0.110017 |
| Lnx7 | 4.84 | 0.206536 |
| Lnx2 | 3.10 | 0.323010 |
| Lnx5 | 2.85 | 0.351479 |
| Lnx4 | 1.63 | 0.613651 |
| Lnx1 | 1.57 | 0.637715 |
| Lnx3 | 1.50 | 0.637715 |
| Mean VIF | 3.51 |  |

## Table 7: Autocorrelation table

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| lags | Chi2 | df | P- value | Durbin-Watson |
| 1 | 13.035 | 1 | 0.003 | 0. 7990 |

## Linearity Graph

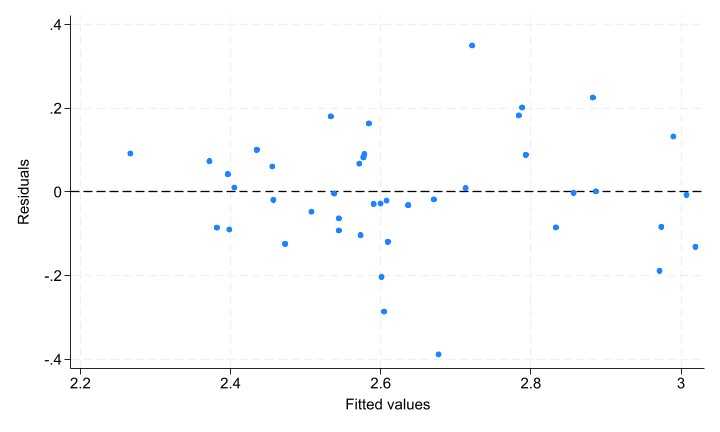
### Figure 1: Linearity Graph

A graph with blue dots

Description automatically generated

.

### Figure 2: Residual Graph



# ARDL MODEL

ARDL(1,0,0,0,1,0,0,0) regression  
Sample: 1971 thru 2013 Number of obs = 43  
 F(9, 33) = 26.09  
 Prob > F = 0.0000  
 R-squared = 0.8768  
 Adj R-squared = 0.8432  
Log likelihood = 46.149608 Root MSE = 0.0944

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| lny | Coefficient | Std. | | err. | t | P>t | [95% | conf. | interval] |
| lny | | |
| L1. | 0.731 | 0.099 | | 7.400 | 0.000 | 0.530 | 0.932 |
|  | | |
| lnx1 | -0.006 | 0.004 | | -1.510 | 0.140 | -0.015 | 0.002 |
| lnx2 | 0.051 | 0.022 | | 2.350 | 0.025 | 0.007 | 0.095 |
| lnx3 | -0.101 | 0.041 | | -2.490 | 0.018 | -0.185 | -0.018 |
|  | | |
| lnx4 | | |
| --. | -0.278 | 0.107 | | -2.600 | 0.014 | -0.496 | -0.060 |
| L1. | 0.352 | 0.107 | | 3.280 | 0.002 | 0.134 | 0.570 |
|  | | |
| lnx5 | 0.037 | 0.692 | | 0.050 | 0.958 | -1.370 | 1.444 |
| lnx6 | -0.041 | 0.036 | | -1.140 | 0.263 | -0.114 | 0.032 |
| lnx7 | -0.018 | 0.010 | | -1.850 | 0.074 | -0.038 | 0.002 |
| \_cons | 0.449 | 2.443 | | 0.180 | 0.855 | -4.522 | 5.420 |
|  | | | | | | | |

## ARDL (HAC)



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# STATA CODES

import excel "C:\Stata code\Gdp.xlsx", firstrow clear

gen training\_set = yr <= 2013

regress lny lnx1 lnx2 lnx3 lnx4 lnx5 lnx6 lnx7 if training\_set ==1

vif

predict inp\_fit if training\_set ==1, residuals

scatter inp inp\_fit if training\_set ==1

rvfplot, yline(0)

Stationarity test using dfuller

dfuller lny if training\_set == 1, trend lag(0)

dfuller lnx1 if training\_set == 1, trend lag(0)

dfuller lnx2 if training\_set == 1, trend lag(0)

dfuller lnx3 if training\_set == 1, trend lag(0)

dfuller lnx4 if training\_set == 1, trend lag(0)

dfuller lnx5 if training\_set == 1, trend lag(0)

dfuller lnx6 if training\_set == 1, trend lag(0)

dfuller lnx7 if training\_set == 1, trend lag(0)

\* Serial correlation (Breusch-Godfrey test)

estat bgodfrey, lags(1)

\* Heteroskedasticity (Breusch-Pagan test)

estat hettest

estat bgodfrey

JOHANSEN COINTEGRATION

vecrank lny lnx1 lnx2 lnx3 lnx4 lnx5 lnx6 lnx7 if training\_set ==1, lags(1) trend(constant) levela max

\*conducting bound test for cointegration

ardl lny lnx1 lnx2 lnx3 lnx4 lnx5 lnx6 lnx7 if training\_set ==1, maxlags(1)

matrix list e(lags)

ardl lnx1 lny lnx2 lnx3 lnx4 lnx5 lnx6 lnx7 if training\_set ==1, lags(1 0 0 0 1 0 0 0) ec btest

ardl lny lnx1 lnx2 lnx3 lnx4 lnx5 lnx6 lnx7 if training\_set == 1, maxlags(1 0 0 0 1 0 0 0) aic

\* HAC robust standard errors for ARDL model

ivreg2 lny L(1/1).lny L(0/0).lnx1 L(0/0).lnx2 L(0/0).lnx3 L(0/1).lnx4 L(0/0).lnx5 L(0/0).lnx6 L(0/0).lnx7 if training\_set == 1, robust bw(3) kernel(bartlett)

Forecasting

\*GENERATING RMSFE

predict lny\_time\_series\_YT\_forecast\_OLS if training\_set == 0

gen SFE = (lny - lny\_time\_series\_YT\_forecast\_OLS)^2 if training\_set == 0

egen SFE\_mean\_vec = mean(SFE)

scalar SFE\_mean = SFE\_mean\_vec[1]

gen RMSFE = sqrt(SFE\_mean)

display RMSFE

\*GENERATING RMAFE

gen AFE = abs(lny - lny\_time\_series\_YT\_forecast\_OLS) if training\_set == 0

egen AFE\_mean\_vec = mean(AFE)

scalar AFE\_mean = AFE\_mean\_vec[1]

gen RMAFE = sqrt(AFE\_mean)

display RMAFE

drop RMSFE RMAFE SFE SFE\_mean\_vec AFE AFE\_mean\_vec

\*HISTORICAL MEAN OF LNY

egen lny\_mean\_vec = mean(lny) if training\_set == 1

scalar lny\_mean\_1 = lny\_mean\_vec[1]

\*GENERATING RMSFE

gen SFE = (lny- lny\_mean\_1)^2 if training\_set == 0

egen SFE\_mean\_vec = mean(SFE)

scalar SFE\_mean = SFE\_mean\_vec[1]

gen RMSFE = sqrt(SFE\_mean)

display RMSFE

\*GENERATING RMAFE

gen AFE1 = abs(lny - lny\_mean\_1) if training\_set == 0

egen AFE1\_mean\_vec = mean(AFE1)

scalar AFE1\_mean = AFE1\_mean\_vec[1]

gen RMAFE1 = sqrt(AFE1\_mean)

display RMAFE1

drop RMSFE RMAFE SFE SFE\_mean\_vec AFE AFE\_mean\_vec