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Enquires and/or comments on the WAFER and published articles should be addressed to:
The Editor- in-chief,
West African Financial and Economic Review
West African Institute for Financial and Economic Management,
CBN Learning Centre
P.M.B 2001, Satellite Town,
Lagos, Nigeria.
Tel: +234 8054407387, +234 8080456007, +234 8146964647
E-mail: capacity@waifem-cbp.org
www.waifem-cbp.org

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MONETARY POLICY AMID COMMODITY PRICE SHOCKS IN COMMODITY-DEPENDENT COUNTRIES: LESSONS USING A BAYESIAN DSGE MODEL

Joseph Kofi Acquah[1], Salamatu Jebuni-Dotsey[2] and Michael Ekow Quansah[3]

Abstract

This paper evaluates how monetary policy should respond to commodity price shocks that impact the current account balance, resulting in macroeconomic imbalances and a wedge between the interbank rate and the monetary policy rate. Over a period of eight quarters, a Bayesian Dynamic Stochastic General Equilibrium model with financial frictions is used to simulate the evolution of key macro-financial variables in response to oil price shocks that impact the current account balance of the Ghanaian Economy. Using impulse response functions, the study finds that when oil price shocks impact the current account balance and generate macroeconomic imbalances that lead to a wedge between the interbank and the policy rate, the monetary policy rate must respond more aggressively to ensure that key macro financial variables return to their steady states. The results show that following a commodity price shock, policy makers should carefully assess how the interbank policy rate are diverging from the monetary policy rate, before further adjustments are made to the monetary policy rate. Ignoring the interest rate wedge may lead to a systemic overestimation (or underestimation) of the monetary policy rate required to dissipate macroeconomic imbalances. Consequently, shocks may linger in the economy for longer than necessary. The results found in this paper are relevant to Sub-Sahara African countries that depend primarily on commodity exports.

Keywords: Monetary Policy, Forecasting and Simulation, Central Banks, Financial Crisis, Commodity Markets,

JEL Classification: E52, E47, E58, G01, Q02

[123]*Research Department, Bank of Ghana*

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Disclaimer: This research paper represents the views of the authors and does not represent the views of the Bank of Ghana. The views articulated herein should be attributed to the authors and not the Bank of Ghana or its Monetary Policy Committee.

1.0 Introduction

Commodity prices largely determine macroeconomic outcomes for commodity-dependent countries (Sanya, 2020). When prices of commodities change suddenly, commodity-dependent countries find that their economic fortunes largely change in line with the changes in commodity prices that they export. When commodity prices increase suddenly, countries that are largely commodity net exporters experience an economic boom (Tahar et al, 2021). On the other hand, when commodity prices fall, these countries experience recessions (Dehn, 2021). The impact that negative commodity price shocks have on macroeconomic outcomes largely stems from the observation that the current account balances of commodity-dependent countries are adversely affected when commodity prices fall. This is because the value of the commodities that they export suddenly fall, while the value of their import remains largely the same, other things being equal. These dynamics often result in a depreciation of the exchange rate, which in turn causes higher inflation and subsequently weakens economic growth (Vo et al. 2019; Mohammed 2021).

The impact that commodity price shocks have on macroeconomic outcomes have been well documented in the literature. Periods of negative commodity price shocks, for example, have been shown in commodity-dependent countries to generate macroeconomic imbalances (Kyei et al, 2021). These shocks have been shown to adversely influence inflation rates, real sector activity, exchange rates, and the trade balance. To dissipate these imbalances, monetary authorities in commodity-dependent countries often adjust their monetary policy rates following a commodity price shock,

to steer inflation back to target and restore key macroeconomic outcomes to their steady states (Tober et al, 2009; Cody et al, 1991; De Gregoria, 2018).

To guide monetary policy decisions, inflation-targeting countries rely on stylized models of their economy (Berg, 2006). Guided by the existing literature, most models succinctly capture how commodity price shocks affect key macroeconomic outcomes such as aggregate demand (output), inflation, and exchange rates (Botha, 2017; Coletti, 1996; Carabenciov, 2008). By modelling the transmission mechanisms, these models have also guided monetary authorities on how the monetary policy rate should be positioned to dissipate macroeconomic imbalances when commodity price shocks arise.

Recent findings in the literature suggest, however, that these models are likely to underestimate the adverse effect of commodity price shocks on the economy. Specifically, they show that commodity price shocks can also have a significant adverse effect on the financial sector (Abaidoo et al, 2021; Babihuga, 2007) as firms that depend on commodity exports for their profits struggle to repay their debts, especially in a high inflationary environment where the currency may be rapidly losing value. Higher default rates weaken bank's balance sheets and profitability, and inadvertently lead to a decrease in lending and tightening of credit conditions. This effect, in turn, can further reinforce adverse macroeconomic outcomes realized from commodity price shocks.

Considering these developments in the literature, this paper builds a Bayesian DSGE model (An et al, 2007) to comprehensively capture the impact of commodity price shocks on macro financial outcomes. Specifically, it models how commodity price shocks affect key macroeconomic variables and the financial sector, as proxied by the evolution of interbank interest rates (the simplest model for financial frictions). By carefully modelling the macro financial effects of commodity price shocks, we show how the model can be used to identify the appropriate monetary policy response needed to dissipate imbalances that emerge from commodity price shocks.

To demonstrate how this model can be useful to commodity-dependent countries, this paper uses Ghana as a case study. Ghana is an ideal case study for three main reasons. First, Ghana is a commodity-dependent country with cocoa, gold, and crude oil contributing more than 80% of its merchandise export (UNCTAD, 2021). Commodity price shocks are, therefore, very relevant in determining macroeconomic outcomes in the economy. Secondly, commercial banks in Ghana significantly lend to commodity producers and traders (Kyei et al 2023). The notion that commodity price shocks can induce higher rates of credit defaults, adversely affect the financial sector, is particularly relevant for Ghana (Okyere and Mensah 2021). Third, Ghana is an inflation-targeting economy with a published stylized model of the economy (Abradu-Otoo, 2022). This transparency allows for this study to retain key features of the stylized model to ensure that the study results are relevant to the country's policy makers.

The paper contributes to the existing literature in several ways. First, it shows how one can use a stylized model to evaluate the impact of commodity price shocks on both macroeconomic and financial sector outcomes. Secondly, it shows how one can use the insights garnered from the model results to position monetary policy rates within an economy, in a manner that dissipates macro financial imbalances over the short to medium term. The model outlined in this paper, can serve as an additional toolkit that may be used by monetary authorities in commodity-dependent countries to inform policy rate decisions that are aimed at dissipating macroeconomic imbalances from commodity price shocks.

The remainder of the paper is organized as follows: Section 2 reviews the literature on the impact of commodity price shocks on macro financial outcomes. Section 3 outlines stylized facts motivating model choice for the Ghanaian economy. Section 4 introduces the Bayesian DSGE model, while section 5 provides an overview of the model calibration and estimation approach. In section 6, we present the model results, following which section 7 discusses the results and their relevance to the literature. Section 8 concludes.

2.0 Literature Review

Impact of Commodity Price Shocks on Macro Financial Outcomes

Commodity price shocks have an enduring impact on macroeconomic outcomes in Sub-Sahara African countries (Fernández, González & Rodriguez, 2018). Using a panel of Sub-Sahara African countries for the period 2005 to 2017, Sanya (2020) finds that increasing prices of export commodities has little positive impact on macroeconomic performance in Sub-Saharan Africa. On the other hand, declines in prices have an adverse impact on macroeconomic outcomes in Sub-Sahara African countries. They conclude that the relationship between commodity price shocks and macroeconomic performance in Sub-Saharan Africa is asymmetric, with negative shocks having greater impact than positive shocks.

The significant impact of negative commodity price shocks on macroeconomic outcomes in Sub-Saharan Africa can be attributed to the observation that negative commodity price shocks largely deteriorate terms of trade for countries within the region. The decline in the terms of trade, thereafter, results in lower national incomes, wider current account deficits, weaker national currencies, inflation, and lower business and consumer confidence, leading to reductions in investment, consumption and economic growth (Roch, 2019).

Within the literature, several studies have documented different magnitudes of the foregoing effects, with the impact largely depending on specific country vulnerabilities, which include the proportion of export earnings derived from primary commodities (Naraidoo & Paez-Farrell, 2023; UNCTAD, 2016).

Negative commodity price shocks can also adversely affect revenues for fiscal authorities significantly. This is because government revenues in SSA are largely dependent on taxes from commodity export earnings. Revenues derived from these taxes are then used to run national budgets (Agenor, 2016). When revenue falls unexpectedly, commodity-dependent countries may find that their fiscal deficits begin to widen. Over time, these countries may find their debt position also increasing rapidly. Consequently, sovereign risk premiums for these countries may also rise as investors begin to price the risk of repayment in their decisions to invest within the

country (Drechsel &Tenreyro, 2017). This further increases debt servicing cost and dampens growth prospects in the medium to long term.

Commodity price shocks can also affect the financial sector adversely. According to Kinda, Mlachil & Ouedraogo (2016), negative commodity prices shocks can weaken the financial sector and increase the probability of banking crises, with the probabilities depending on the severity of the shock. In their study, commodity price shocks, which tend to reduce fiscal revenue and firm profits were shown to also reduce bank profits as non-performing loans, bank costs, and provisioning rise in response to these shocks. In the financial sector this has been shown to significantly increase lending rates, as risk premiums heighten and credit contracts. When negative commodity price shocks are severe, a full-blown banking crisis can potentially ensue, further worsening macroeconomic outcomes (Siklos 2021; Tahar et al. 2021).

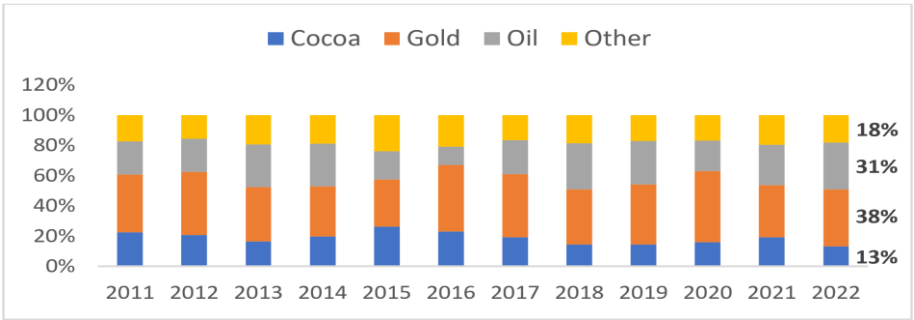
From the literature it is clear that a stylized model that aims to capture the impact of commodity price shocks on an economy, must necessarily capture the effects that such shocks have on both macroeconomic and financial sector outcomes. The Bayesian DSGE model with financial frictions provides a framework through which the effects of these shocks on macro-financial outcomes can be succinctly captured.

3.0 Stylized Facts and Model Motivation for the Ghanaian Economy

The Ghanaian economy is a small open economy that relies on 3 main commodities for its exports, namely cocoa, gold, and oil[4]. In 2022, for example, gold exports contributed the most to total exports (38%), followed by oil (31%), cocoa (13%) and other exports (18%). These 3 commodities, for the larger part of the decade, have played a sizeable role in export earnings for the Ghanaian economy, as shown in Figure 1. As a share of total exports, these 3 commodities have broadly contributed 80 percent to export earnings within the Ghanaian economy.

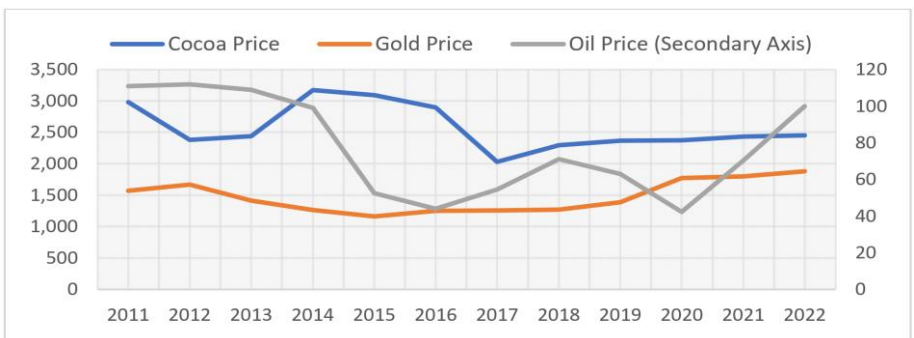
[4] Commercial quantities of oil began in December 2010, after Ghana discovered crude oil in 2007

Figure 1: Key Commodities as a Share of Total Exports of Ghana



Export proceeds for the Ghanaian Economy from these 3 commodities have been volatile, largely reflecting the volatility of prices in Gold, Oil and Cocoa (Kyei et. al, 2023). From 2011 to 2022, for example, the prices of Gold, Oil and Cocoa varied significantly, as shown in Figure 2. The average price for Gold per year, varied over the period, from a minimum of USD 1,159 per fine ounce (realized in 2015), to a maximum of USD 1,880 per fine ounce (realized in 2022). Oil, on the other hand, varied from a minimum of USD 42 per barrel (realized in 2020) to USD 112 per barrel (realized in 2012). Cocoa prices also ranged from USD 2,029 per tonne (in 2017) to USD 3171 per tonne (in 2014).

Figure 2: Average International Prices of Key Export Commodities of Ghana by Year



Variation in commodity prices affect the terms of trade, the value of export earnings, and macro financial outcomes for commodity-dependent countries, such as Ghana (Jena 2017; UNCTD, 2021; Cantah 2018). Using a Time-Varying Parameter Vector Autoregressive model on selected economic authors, Kyei and co-authors (2023) confirm the relationship between commodity prices and macro financial outcomes in Ghana. Specifically, they find that international commodity prices strongly influence the inflation rate, real output (using the composite index of economic activity), broad money (interest rates), exchange rate, and trade balances in the Ghanaian economy.

The impact of commodity price shocks on inflation rates, real output, exchange rates, and interest rates within the domestic economy, has implications for monetary policy, especially for countries like Ghana, that are inflation targeting. Under the inflation-targeting regime, monetary policy in Ghana is designed to influence the inflation forecast and to keep inflation at the medium-term target of 8 percent, with a symmetrical tolerance band of 2 percent. To ensure that this is attained, monetary policy formulation is vested in the Monetary Policy Committee, which meets every two months to decide on the monetary policy rate deemed appropriate to steer inflation towards its target over the medium term. The decision on the monetary policy stance is made after careful evaluation of the inflation forecast, as well as a detailed review of macro financial data relevant to the Ghanaian economy.

The Bank's core macroeconomic model used for inflation forecasts is the Quarterly Projection Model (QPM), a version of the Semi-Structural New Keynesian model (McCaw et al, 2005). The model consists of four core blocks – the Aggregate Demand Block, Philips Curve Block, Exchange Rate Block, and Interest Rate Block which includes a monetary policy reaction function that highlights the monetary policy response needed to steer inflation back to its target in the medium term (Abradu-Otoo, 2022). Together, these four blocks provide a stylized version of the Ghanaian economy, characterizing the dynamic interactions of key macroeconomic variables - aggregate demand (output), interest rates, exchange rates, and inflation under the inflation-targeting framework.

In view of the stylized representation of the Ghanaian economy used by monetary authorities, this study retains the four core blocks that capture the key dynamics of macroeconomic variables within the economy. It relies, however, on a Bayesian Dynamic Stochastic General Equilibrium (DGSE) model to trace out the impact of commodity price shocks on macro financial outcomes within the economy, and the appropriate monetary policy response needed to mitigate its effect on the economy. The choice to use the Bayesian DSGE model in this study is based on the advantages the model proffers, which includes a micro-founded perspective on the transmission mechanisms of shocks and policy interventions (Zheng and Guo, 2013)[5], and the derivation of a dynamic optimal response function, which are valid, even when economic conditions change (thereby potentially mitigating the Lucas critique (1976)).

To capture the effects of commodity price shocks on the Ghanaian economy, the Bayesian DSGE model begins at an equilibrium whereby inflation is at target, output is at its potential, the real exchange rate is at its long-term trend, and the monetary policy rate is neutral. As shown in prior studies, a commodity price shock is likely to lead to a deviation from equilibrium in the four key macroeconomic variables within the economy – real output, interest rates[6], exchanges rates and inflation – due to the interconnectedness between commodity prices, the current account balance, and macro financial outcomes for commodity-dependent economies (Kyei et al., 2023). To ensure that deviations from equilibrium dissipate over the medium to long term, the monetary policy reaction function from the Bayesian DSGE model will provide an optimal monetary policy path that prevents inflation from drifting away from its target, while ensuring that output, interest rates, and exchange rates all return to their equilibrium values.

The significant role that commodities play in determining export earnings and the current account balance (UNCTD, 2021), the dependence of macro financial outcomes on commodity prices (Kyei et al. 2023), and the inflation-targeting framework used

[5] Since it outlines the optimal behaviour of consumers and firms.
[6] Impact on the interest rate, succinctly captures the impact of commodity price shocks on the financial sector. As prevailing interest rates diverge from the monetary policy rate, they signal financial distress.

by monetary authorities (Abradu-Otoo, 2022), makes Ghana a suitable country to assess how commodity price shocks affect macro financial outcomes. More importantly, by adapting the countries stylized model of the economy to the Bayesian DSGE model, one can effectively trace how the monetary policy rate can be used to steer inflation to the medium-term target, when deviations due to commodity price shocks occur.

4.0 The Bayesian DSGE Model

Aggregate Demand Block

The aggregate demand block in the Bayesian DSGE model expresses the dynamic relationship between the output gap[7] and other macroeconomic variables. It relates the domestic output gap ($outgp$) to the expected future output gap ($Eoutgp$), interest rates ($intr$), expected inflation ($Einf$), changes in the current account balance (Δcab), growth rate of technology ($\Delta tech$), and the expected foreign output gap ($Eoutgp^{frgn}$).

$$outgp_t = Eoutgp_{t+1} - (\tau + \lambda)(intr_t - Einf_{t+1}) + \alpha(\tau + \lambda)\Delta cab_{t+1} + \rho\Delta tech_t + \frac{\lambda}{\tau} Eoutgp_{t+1}^{frgn} \quad (1)$$

To ensure stationarity of the model, all real variables are expressed in terms of their deviations from the steady state. For this study, the current account balance variable is key, since it captures the open economy features of the model and the channel through which commodity prices (such as oil, gold and cocoa prices) affect macro financial outcomes. The parameter α, which is assumed to be positive and between 0 and 1, captures how much the external sector affects domestic output[8]. The parameter τ captures the intertemporal elasticity of substitution, while λ captures the impact that the foreign output gap has on domestic output gap. The equation for the aggregate demand block (euler equation) can be derived from a household optimisation problem with a representative agent (Zheng and Guo, 2013).

[7] Defined as deviation of output from its trend.
[8] In a closed economy, this parameter would simply be zero.

Phillips Curve Block

The Phillips Curve Block of the Bayesian DSGE model characterises the dynamic relationship between inflation and other macroeconomic variables. It relates inflation (inf) to expected inflation ($Einf$), expected changes in the current account balance ($\beta Ecab_{t+1} - cab_t$) and the output gap ($outgp_t$).

$$inf_t = \beta inf_{t+1} + \alpha(\beta Ecab_{t+1} - cab_t) + \frac{ps}{\tau + \lambda} outgp_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Expected current account balance, in the firm's optimisation, is multiplied by the parameter beta (β), which is the discount rate for the representative household. The parameter ps, on the other hand, captures the level of price stickiness in the economy; with smaller values for the parameter denoting an economy with a high degree of price stickiness (or vice versa). The equation for the Phillips Curve Block can be derived from a firm's optimisation problem with a representative agent (Zheng and Guo, 2013)

Exchange Rate Block

The Exchange Rate Block reflects the theory of relative purchasing price parity which says that the change in the exchange rate reflects an inflation differential between the domestic economy and a foreign economy. To capture the influence of commodity price shocks, this theory is further modified to include the effects that the current account balance has on the depreciation rate. Specifically, the depreciation rates (depr) are determined by the inflation rate differential ($inf_t - inf_t^{frgn}$) and changes in the current account balance (Δcab).

$$\text{depr}_t = inf_t - inf_t^{frgn} - (1 - \alpha)\Delta cab_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Interest Rate Block

The interest rate block consists of 3 equations. The first equation captures the notion that interest rates in the market are related to the monetary policy rate and an interest rate-monetary policy rate gap term ($intr\_mpr\_gap$) .

$$\text{intr}_t = \gamma_{\text{impr}} mpr_t + intr\_mpr\_gap \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The interest rate-monetary policy rate gap, is included in the equation above, to represent changes in interest rates (interbank rates) that are independent of the

monetary policy stance. Amid commodity price shocks, monetary authorities may find that prevailing interest rates diverge from the monetary policy rate due to changes in money demand arising from financial distress. The interest rate monetary policy rate gap term succinctly captures this notion. It also captures the idea that deviations from the monetary policy rate could be persistent. Specifically, the dynamics of the interest rate monetary policy rate gap follows an AR (1) process as shown below:

$intr\_mpr\_gap_t = \eta intr\_mpr\_gap_{t-1} + \epsilon_t^{intr\_mpr\_gap}$ ....(5)

The gap is the simplest representation of a financial frictions model. Finally, the interest rate block includes the Central Bank monetary policy reaction function. The function assumes that to achieve its objective of price stability and to dissipate imbalances within the economy, the Central Bank's monetary policy rate (mpr) will respond to the inflation rate (inf), output gap ($outgp$), and the US dollar/cedi depreciation rate (depr).

$mpr_t = \theta_{is} mpr_{t-1} + (1-\theta_{is})\left[\phi_{inf} inf_t + \phi_y outgp_t + \phi_e \mathrm{depr}_t\right] + \varepsilon_t^{mpr}$ ... .(6)

To capture a desire for smoothness, the Central Bank's monetary policy rate is assumed to change with a consideration of what the previous rate was (Xie & Zhang, 2002). This is captured succinctly by the parameter θ_{is} which is between 0 and 1. Deviations of the monetary policy rate from the rates suggested by the central bank monetary policy reaction function is captured by the shock term in equation 6 (ε_t^{mpr}).

Exogenous Trends

Evolution in the current account balance, technological change, foreign output and foreign inflation are all assumed to be exogenous in the model. These variables are assumed to follow an AR(1) process as expressed below:

$\Delta cab_t = \gamma_{cab} \Delta cab_{t-1} + \varepsilon_t^{\Delta cab}$...(7)

$\Delta tech_t = \psi_{tech} \Delta tech_{t-1} + \varepsilon_t^{\Delta tech}$ ... ...(8)

$\mathrm{outgp}_t^{\mathrm{frgn}} = \kappa_{outgp\_frgn} outgp_{t-1}^{frgn} + \varepsilon_t^{\mathrm{outgp\_frgn}}$.. ... ...(9)

$inf_t^{frgn} = \kappa_{\mathrm{inf}\_frgn} \mathrm{inf}_{t-1}^{\mathrm{frgn}} + \varepsilon_t^{\mathrm{inf\_frgn}}$ ... ... (10)

Equation 1 through 10 defines the Bayesian DSGE model for the Ghanaian Economy. Through this model, the transmission mechanism for commodity price shocks that manifest through changes in the current account balance would be outlined for the Ghanaian economy.

5.0 Model Calibration and Estimation of Parameters

5.1 Data

Data used to estimate key parameters for the Bayesian DSGE Model were sourced from the Bank of Ghana, Ghana Statistical Services and the Federal Reserve Bank of St. Louis. The data used in the analysis spanned from 2006 quarter 1 to 2021 quarter 4. The table below shows summary statistics for the variables used for the Bayesian DSGE model.

Table 1: Summary Statistics of Data used for Bayesian Estimation

Variable	Mean	SD
Output gap	-0.22	2.22
Inflation	13.57	6.38
Monetary policy rate	17.13	3.94
Interest rates	16.96	4.97
Growth of current account balance	-0.05	0.03
Depreciation rate	3.58	5.55
US inflation	2.41	2.01
US real output gap	0.00	269.19

Data on Ghana's real GDP, monetary policy rate, interest rates, depreciation rate and current account balance were extracted from the Bank of Ghana's Quarterly Statistical Bulletin, as published on the official website. The inflation rate used in this study reflects the year-on-year changes in the Consumer Price Index (CPI) as published by the Ghana Statistical Service. The US output gap and inflation rate were extracted from the Congressional Budget Office and the Federal Reserve Bank of St Louis respectively.

The output gap used in this study is defined as the deviation between the real output (real GDP), and the potential real output as measured by the Hodrick-Prescott (HP) trend. To gauge the relative size of the current account balance relative to the overall economy, the current account balance is divided by GDP (Kent and Cashin, 2003). For the Ghanaian economy, improvements in the current account balance as a share of GDP has been linked to improvements in the terms of trade of its key commodity exports, including oil, gold, and cocoa (Yeboah, 2023).

5.2 Priors for the Bayesian DSGE Model

Priors in the Bayesian DSGE Model, which will be used alongside the study data to estimate the Bayesian DSGE model parameters, is given below in Table 1. The prior's used in the Bayesian DSGE model were largely informed by existing literature (Zheng and Guo, 2013; Owusu-Afriyie and Farouke, 2022), stylized facts, and expert judgement.

Table 2: Prior Distribution of Parameters

Parameter	Interpretation	Density Function	Parameter (1)	Parameter (2)
	Aggregate Demand Block			
τ	Intertemporal substitution elasticity	Beta	0.50	0.50
λ	Foreign output gap effects on domestic gap	Beta	0.50	0.20
α	Degree of Openness	Beta	0.25	0.75
ρ	Technological growth effects on output gap	Beta	0.50	0.25
	Phillips Curve Block			
β	Discount factor	Beta	0.50	0.20
ps	Price stickiness measure	Beta	0.50	0.25
	Interest Rate Block			
θ_{is}	Interest rate smoothing parameter	Beta	0.50	0.50
ϕ_{inf}	Inflation Coefficient	Beta	0.95	0.05

ϕ_y	Output gap coefficient	Beta	0.95	0.05
ϕ_e	Depreciation coefficient	Beta	0.10	0.75
γ_{impr}	AR(1) Coefficient capturing the correlation between the interest rate and monetary policy rate	Beta	0.80	0.20
η_w	AR(1) Coefficient capturing the persistence of the interest rate-monetary policy rate gap across time	Beta	0.50	0.50
	Exogenous Trends			
γ_{cab}	AR(1) Coefficient determining the dynamics for the current account balance	Beta	0.50	0.20
κ_{yf}	AR(1) Coefficient determining the dynamics for the foreign output gap	Beta	0.50	0.20
$\kappa_{\pi f}$	AR(1) Coefficient determining the dynamics for foreign inflation	Beta	0.50	0.20
ψ_{tech}	AR(1) Coefficient determining the dynamics for technological growth	Beta	0.50	0.25
	Shocks			
$\sigma(\epsilon^{mpr})$	Standard deviation: policy rate shocks	Inverse Gamma	0.10	2.00
$\sigma(\epsilon^{\Delta cab})$	Standard deviation: current account shocks	Inverse Gamma	1.50	2.00
$\sigma(\epsilon^{tech})$	Standard deviation: technology shocks	Inverse Gamma	0.10	2.00
$\sigma(\epsilon^{y^f})$	Standard deviation: foreign output gap shocks	Inverse Gamma	1.50	2.00
$\sigma(\epsilon^{\pi^f})$	Standard deviation: foreign inflation shocks	Inverse Gamma	0.50	2.00
$\sigma(\epsilon^{w})$	Standard deviation of shocks: market wedge	Inverse Gamma	0.50	0.20

5.3 Estimation of Model Parameters

Parameters for the Bayesian DSGE model were estimated using the Metropolis-Hastings sampling algorithm. The algorithm relies on the Markov Chain Monte Carlo (MCMC) statistical process and utilizes a large sample size to improve sampling efficiency. Specifically, for this study, parameters were blocked for independent sampling, while the burn-in period and the number of iterations used for the MCMC were set at 10,000 and 30,000, respectively. Convergence diagnostics for all parameters are provided in the appendix of this study.

6.0 Empirical Findings

6.1 Parameter Estimates

The parameter estimates for the Bayesian DSGE model are provided below.

Table 3: Model Estimation Results

Parameter	Interpretation	Mean	95% CI
τ	Intertemporal substitution elasticity	0.43	[0.35,0.53]
λ	Foreign output gap effects on domestic gap	0.61	[0.47,0.73]
α	Degree of Openness	0.25	[0.17,0.34]
ρ	Technological growth	0.60	[0.52,0.68]
β	Discount factor	0.90	[0.86,0.93]
ps	Price stickiness measure	0.72	[0.63,0.81]
θ_{is}	Interest rate smoothing parameter in Monetary Policy Reaction (MPR) Function	0.76	[0.72,0.80]
ϕ_{inf}	Inflation Coefficient in MPR function	0.94	[0.90,0.98]
ϕ_y	Output gap coefficient in MPR function	0.95	[0.90,0.98]
ϕ_e	Depreciation coefficient in MPR function	0.11	[0.06,0.17]
γ_{impr}	AR(1) Coefficient capturing the correlation between prevailing interest rates and the monetary policy rate	0.86	[0.82,0.91]
η	AR(1) Coefficient capturing the persistence of the interest rate- monetary policy rate gap	0.58	[0.49,0.66]

Parameter	Interpretation	Mean	95% CI
γ_{cab}	AR(1) Coefficient determining the dynamics of the current account	0.69	[0.58,0.79]
κ_{yf}	AR(1) Coefficient determining the dynamics of foreign output gaps	0.95	[0.93,0.97]
$\kappa_{\pi f}$	AR(1) Coefficient determining the dynamics of foreign inflation	0.69	[0.57,0.80]
ψ_{tech}	AR(1) Coefficient determining the dynamics for technological growth	0.60	[0.52,0.68]
$\sigma(\epsilon^{mpr})$	Standard deviation: policy rate shocks	0.94	[0.75,1.20]
$\sigma(\epsilon^{\Delta cab})$	Standard deviation: current account balance shocks	0.05	[0.04,0.06]
$\sigma(\epsilon^{tech})$	Standard deviation: technology shocks	11.06	[7.83,15.45]
$\sigma(\epsilon^{y^f})$	Standard deviation: foreign output gap shocks	0.75	[0.41,1.29]
$\sigma(\epsilon^{\pi^f})$	Standard deviation: foreign inflation shocks	6.51	[5.50,7.75]
$\sigma(\epsilon^{w})$	Standard deviation of shocks: market wedge	1.42	[1.19,1.70]

From the model estimation, we find that Ghanaian households are relatively inelastic in substituting future consumption for current consumption ($\tau = 0.43$). This is consistent with the high discount factor estimated ($B = 0.90$). In line with a small-open economy, the influence of the foreign output gap, technological growth, and current account balance on domestic output are respectively shown to be sizable ($\lambda = 0.61, \rho = 0.60\ \alpha = 0.25$). In addition, prices in the economy, per the Bayesian estimates, are not sticky ($ps = 0.72$). Specifically, whenever output increases from its trend by 1 percentage point, inflation increases by 0.72 percentage points.

Monetary policy in this model is estimated to react to inflation, the output gap, and depreciation. Relative to depreciation, the monetary policy reaction function reacts aggressively to the inflation rate and the output gap. If inflation increases by 1 percentage point, beyond the target, the monetary policy rate is increased by 94 basis points ($\phi_1 = 0.94$). Similarly, if output gap increases by 1 percent point, the monetary policy rate is increased by 95 basis points ($\phi_2 = 0.95$). In contrast, the monetary

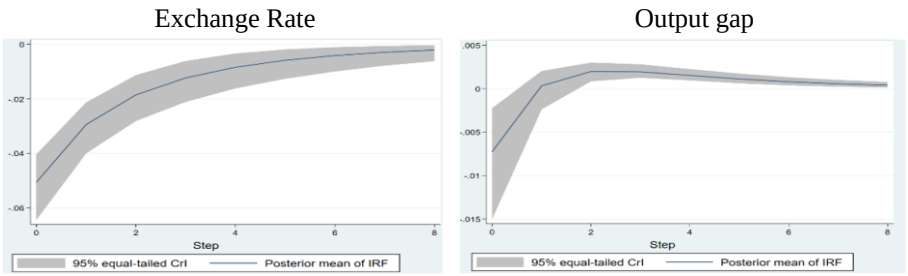
policy rate is raised by only 11 basis points when depreciation rate increases by 1 percentage point ($\phi_3 = 0.11$). Per the estimates, the central bank also shows a strong willingness to smoothen the movement of the interest rate ($\theta = 0.76$). The interest rate block also shows that in the Ghanaian economy, the monetary policy rate is highly correlated with prevailing interest rates as proxied by the interbank rate ($\gamma_{impr} = 0.86$); a characteristic of inflation targeting regimes. Whenever deviations occur between the interbank rate and the monetary policy rate, due to commodity price shocks, for example, the interest rate-monetary policy rate gap that emerges, converges to a steady state of zero relatively quickly ($\eta = 0.58$).

All exogenous variables also show some persistence in their trends. In order of magnitude, the foreign output gap shows the highest persistence ($\kappa_{yf} = 0.95$), followed by the current account balance ($\gamma_{tot} = 0.69$), foreign inflation ($\kappa_{\pi f} = 0.69$) and technological growth ($\psi_{tech} = 0.60$).

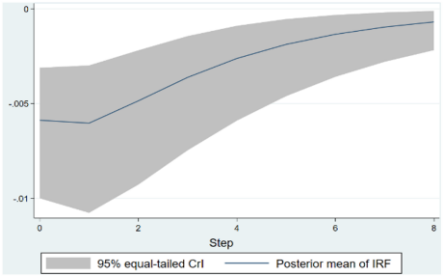
6.2 Impulse Response Functions

To assess the impact of commodity prices shocks on key macroeconomic outcomes, the impulse response functions from the Bayesian DSGE Model are shown below. The impulse responses show that a positive unit shock to the current account balance, induced by an unexpected increase in commodity prices leads to an appreciation of the exchange rate (USD/cedi) in the short run for the Ghanaian economy (vice versa for a negative commodity price shock).

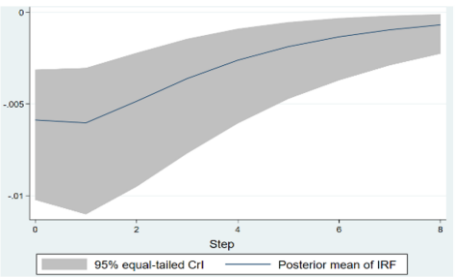
Figure 3: Model impulse Response Functions



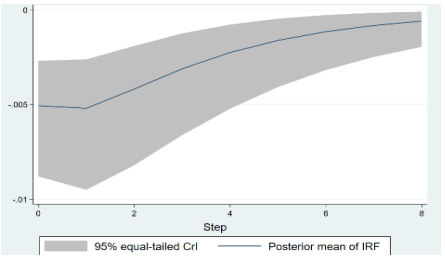
Inflation



Monetary policy rate



Interbank Rate



With the appreciation of the currency, external demand for Ghanaian goods and services declines, leading to a fall in the output gap. The decline in aggregate demand, as proxied by the output gap, then leads to a decline in inflation.

In response to the negative output gap and inflation falling below target, the central bank reduces its monetary policy rate, thereby effectively taking an accommodative monetary policy stance to stimulate aggregate demand and to steer inflation back to target. From the impulse response functions, we find that due to the accommodative monetary policy stance taken immediately by the central bank, the output gap slowly converges to zero, pulling inflation back to target. In line with the reduction in the monetary policy rate, the real exchange rate also begins to depreciate until it also reaches its steady state.

It is important to note that to ensure that interest rates are optimally set to correct imbalances within the economy, the Central Bank reduces the monetary policy rate by more than the target decline in the interbank rate. This is largely to account for the wedge between the monetary policy rate and the interbank rate; which succinctly represents financial frictions in the economy (Brzoza-Brzezina et al, 2013).

An insightful exercise entails assessing how the dynamics of the economy would evolve without the presence of financial frictions. To answer this question, we compare results from the study model to a model without financial frictions (i.e $\epsilon_t^{intr\_mpr\_gap} = 0$)

Table 4: Dynamics of key economic variables with and without financial frictions

	Output Gap (%)		Inflation (%)		Depreciation Rates (%)	
Quarters	With Financial frictions	Without Financial frictions	With Financial frictions	Without Financial frictions	With Financial frictions	Without Financial frictions
0	-0.73	-0.66	-1.32	-1.28	-5.06	-5.00
1	0.03	0.04	-0.38	-0.38	-2.95	-2.93
2	0.20	0.18	-0.09	-0.11	-1.86	-1.87
3	0.19	0.18	-0.01	-0.03	-1.24	-1.25
4	0.15	0.14	0.01	0.00	-0.85	-0.86
5	0.11	0.10	0.01	0.00	-0.59	-0.60
6	0.08	0.07	0.01	0.00	-0.42	-0.42
7	0.06	0.05	0.01	0.00	-0.30	-0.30
8	0.04	0.03	0.00	0.00	-0.21	-0.21

From the table above, we find that the adverse impact of commodity price shocks on key macroeconomic outcomes are slightly elevated in an economy with financial frictions. In response to a positive unit shock to the current account balance, exchange rates in an economy with financial frictions immediately appreciate by an additional 0.06 (5.06-5.00) percentage points (in quarter 0), while the output gap and inflation rates fall by an additional 0.07 and 0.04 percentage points, respectively. These results

broadly reflect the notion that financial distress induced by commodity price shocks, will likely reinforce any adverse macroeconomic outcomes that emerge from the shock. These differences, however, narrow 8 quarters ahead, as monetary policy across the models respond in a manner that dissipate imbalances that emerged from the commodity price shock.

Comparing monetary policy responses across models with and without financial fractions, we find that monetary policy, amid financial frictions is slightly more aggressive. Specifically, from the table below, we find that in response to a positive unit shock to the current account balance, a model that correctly captures financial frictions, when they exist, would on average be lower by 2.7 basis points in every quarter until the imbalances dissipate[9].

Table 5: Monetary Policy Responses accounting for potential interest rate gaps that may emerge from commodity price shocks

	Monetary Policy Rates Basis Point		
Quarters	**With Financial Frictions**	**Without Financial Frictions**	**Basis Point Difference**
0	-0.59	-0.55	-4.0
1	-0.60	-0.55	-5.0
2	-0.49	-0.44	-5.0
3	-0.36	-0.33	-3.0
4	-0.26	-0.24	-2.0
5	-0.19	-0.17	-2.0
6	-0.13	-0.12	-1.0
7	-0.10	-0.09	-1.0
8	-0.07	-0.06	-1.0
Average	-0.31	-0.28	-2.7

[9] It is important to note that the larger the shock, the larger the differences across the model.

A central bank that ignores financial frictions arising from commodity price shocks in its model, may discover that the imbalances caused by these shocks take longer to dissipate. The intuition for this is straightforward; by ignoring financial frictions that may emerge from commodity price shocks, the model for the economy informing how monetary policy should react to dissipate imbalances may erroneously discount how aggressive monetary policy rate would have to be to correct the imbalances that have emerged. This is because its forecast of adverse macroeconomic outcomes, as shown above, would likely be underestimated.

6.3 Contextualizing the Results for the Ghanaian Economy

Ghana is largely a commodity-dependent country where exports of gold, oil, and cocoa play a significant role in determining the export earnings of the country. Gold, oil, and cocoa together contribute more than 80% of merchandise export (UNCTAD, 2021). When prices of these commodities increase, export earnings increase, which, all else equal, will lead to an improved current account balance. On the other hand, when prices of these commodities fall unexpectedly, export earnings can decline rapidly, deteriorating the current account balance, and adversely affecting macro financial outcomes.

In recent history, since the discovery of oil in 2010, export earnings in the Ghanaian economy have largely been stable; with one exception. From mid-2014 to early 2016 oil prices dropped suddenly, by almost 70 percent, due to a sudden oversupply of petroleum. This boom in oil production was largely due to advances in hydraulic fracturing and horizontal drilling technologies, which increased oil production over the period. The sharp fall in oil prices significantly affected export earnings in 2014 and 2015. Specifically, export earnings in the Ghanaian economy declined by approximately 4 per cent in 2014, and 22 percent in 2015, before rebounding in 2016, to 8 percent[10].

[10] The decline in export earnings in 2014 and 2015, was unprecedented since the discovery of oil in 2010.

Figure 4: Export Earnings in the Ghanaian Economy

Before the oil price shock in 2014, the Ghanaian economy was also experiencing an electricity crisis (Kupzig, 2023). This electricity crisis, which began in late 2012 was characterised by severe power rationing which adversely affected firm's productivity and profitability. In light of these developments, market rates (as proxied by the average lending rate of banks) begun to diverge from the monetary policy rate in 2012, signalling the emergence of financial frictions within the Ghanaian economy.

The Bayesian DSGE model developed in this study, which assesses how commodity price shocks would affect an economy with financial frictions, is particularly suitable in assessing how the negative oil price shock would affect the Ghanaian economy; especially in 2014 (the year of the the oil price shock) [11]. Relying on impulse response functions, previously derived, the Bayesian DSGE model predicts that in response to the negative oil price shock, the real exchange rate would depreciate in 2014. This, all else equal, should lead to a positive output gap, which should lead to an increase in

[11] The dynamics of the macroeconomy, post 2014, is also largely affected by other factors that emerged during the electricity crisis. Hence the focus on the year 2014.

the inflation rate. In response, the monetary authorities, cognizant of existing financial frictions, would increase the monetary policy rate aggressively to steer inflation back to target. This hypothesis is largely confirmed by the historical data.

Table 6: Selected Macro financial Indicators

	Year									
Key Macroeconomic Indicators	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Average Change: Real Exchange Rate (%)	-10	-3.2	-23.4	-7.5	8.9	-1.1	-0.2	-13.2	5.0	1.2
Average Output Gap (%)	2.0	4.2	1.4	-1.4	-1.5	-1.3	0.5	2.2	-0.7	1.7
Average GDP Deflator (%)	15.2	15.8	23.9	13.3	15.7	10.7	10.6	8.5	9.4	12.1
Average Monetary Policy Rate (%)	14.5	15.8	18.5	23.0	25.9	22.3	17.7	16.0	14.8	14.0
Average Lending Rate	14.4	17.4	21.8	24.2	25.4	22.4	17.0	15.3	14.2	13.0

Specifically, in 2014, the real exchange rate depreciated on average by 23.4 percent on a year-on-year basis, as compared to an average of 3.2 percent a year prior. This increase in the depreciation rate made exports in the Ghanaian economy cheaper, fuelling aggregate demand and leading to a positive output gap in 2014. Inflation, as proxied by the GDP deflator, also increased sharply in the year to 23.9 percent, from 15.8 percent the year prior. In view of the imbalances, the monetary authorities further increased the monetary policy rate to an average of 18.5 percent in 2014 from an average of 15.8 percent in the prior year. The monetary policy rate, to steer inflation back to target, was further increased in 2015 and 2016, until it begun an easing cycle in 2017. The aggressive tightening cycle by monetary authorities enabled the inflation rate to taper to its medium-term target of 8 plus or minus 2 percent in 2019. The dynamics of key macroeconomic variables and the monetary policy response,

following the oil price shock, are largely in line with predictions from the impulse response functions derived from the Bayesian DSGE model discussed earlier.

The experience of the Ghanaian economy during the oil price shock of 2014 highlights how the Bayesian DSGE model can be used to understand and predict the dynamics of key macroeconomic variables, in countries facing commodity price shocks amid financial frictions.

6.4 Discussion

Many developing and emerging economies depend on their commodity exports for their revenue (UNCTAD, 2021). When commodity prices fall, leading to a decline in the current account balance, key macroeconomic variables such as inflation, output, and the exchange rate are impacted in the short to medium term (Chuku et al, 2018, Céspedes and Velasco 2012).

Recent literature has highlighted, that beyond macroeconomic outcomes, commodity price shocks also affect the financial sector adversely. Commodity price shocks, which can lead to high inflation, declines in aggregate demand, and rapid fluctuations in exchange rates, can impact borrowers' ability to repay their debts (Abaidoo et al. 2021, Kinda et al. 2018). With higher non-performing loans, banks may find their profitability decreasing, which inadvertently weakens their balance sheets. In response to rising credit risks, banks may increase their demand for excess reserves, which could lead to higher interest rates in the interbank market and on loans that they advance. This, in turn, would tighten credit conditions within the economy further and exacerbate any initial adverse impacts that commodity price shocks may have had on the economy (Borio and Drehmann 2011).

Two key insights are offered by recent literature on the effect that commodity price shocks have on macro financial outcomes. The first, is the idea that, a comprehensive assessment of the impact of commodity price shocks on the economy, should include its impact on the financial sector. The second insight is that the impact of commodity price shocks on the financial sector and macroeconomic outcomes are reinforcing. Modellers or researchers that ignore this reinforcing mechanism may therefore likely

underestimate the impact that commodity price shocks can have on macro financial outcomes.

These insights have succinctly been catered for in the Bayesian DSGE model used in this study. First, it illustrates how deterioration in the current account balance, due to commodity price shocks, can affect the financial sector. Specifically, when commodity price shocks affect the profitability of banks and weaken their balance sheet, the DSGE model, developed in this study, allows for the financial sector to respond by increasing interest rates in a manner that leads to a divergence between market interest rates and the monetary policy rate[12]. Second, by developing a stylized model of the economy based on the optimal response functions of households and firms, a micro-founded perspective on the transmission mechanisms of shocks and policy interventions are provided. The transmission mechanisms, derived from the dynamic optimal response function of economic agents, remain valid even when economic conditions change (thereby potentially mitigating the Lucas critique (1976)).

Using the Ghanaian economy, as a case study, we show how monetary authorities can use the Bayesian DSGE model to predict how macro financial outcomes would be affected from commodity price shocks that affect the current account balance. Specifically, we show, that in the Ghanaian economy, positive (negative) commodity price shocks that affect the current account balance led to an appreciation (depreciation) of the currency, and a decline (increase) in the output gap and inflation. We also show that when financial frictions are present, the monetary policy rate would have to be more aggressive in determining market interest rates. The intuition here is simple; When market interest rates diverge from the monetary policy rate, due to financial distress, the monetary policy rate would have to do more to anchor market interest rates moving forward.

The Bayesian DSGE model, in this study, effectively combines different strands of the literature. The first set of literature entails studies that have documented the nexus

[12] Where the divergence signals the level of financial distress induced by the commodity price shock

between commodity prices and macroeconomic variables (Chuku et al, 2018; Cespedes et al, 2012; Sanya, 2020). The second set entails studies that have shown how macroeconomic variables affect the financial sector (Ghauri et al. 2019; Siklos 2021; Kinda et al 2016), while the third and final set of literature, assesses how monetary policy should respond to commodity price shocks (Tober et al, 2009; Cody et al, 1991; De Gregoria, 2018).

By combining these strands of literature into a single model, the Bayesian DSGE model developed in this paper, effectively captures the impact that commodity price shocks can have on macro financial outcomes. More importantly, study results also show that simpler models that ignore the effect that commodity price shocks have on both the macroeconomy and the financial sector, are likely to systematically underestimate the monetary policy response needed to dissipate imbalances within the economy. This model can, therefore, be an effective addition to monetary policy toolkits used by commodity-dependent countries, to guide the effective positioning of their monetary policy rates.

8.0 Conclusion

Commodity-dependent economies are often vulnerable to commodity price shocks as their macro financial outcomes are largely determined from the evolution of commodity prices. Given the negative pass-through effect of commodity price shocks on financial sector outcomes, this study demonstrates that the monetary policy response should be more aggressive when these shocks create a gap between prevailing market rates—represented by the interbank rate—and the monetary policy rate. Failing to account for this gap in monetary policy decisions could result in macroeconomic imbalances persisting in the economy for longer than necessary.

This study has also added to the literature on commodity price shocks, by showing how the Bayesian DSGE small-open economy model can be better utilized to understand how deteriorations in the current account balance, from commodity price shocks, can affect macro-financial outcomes, for economies with existing financial frictions or for economies where commodity price shocks induce financial frictions; as proxied by a wedge between the interbank rate and the monetary policy rate. By

carefully mapping out the transmission mechanism using impulse response functions, central planners can identify various points for intervention. By also calibrating the Bayesian DSGE model appropriately, monetary authorities can also estimate how much monetary policy rates need to respond to commodity price shocks that affect the current account balance amid financial frictions. Carefully done, this model can improve the efficacy of monetary policy.

The model outlined in this paper, can serve as an additional toolkit used by monetary authorities in Sub-Saharan Africa to inform policy rate decisions aimed at dissipating macroeconomic imbalances from commodity price shocks. The model in this study relies primarily on Ghana data, but a similar exercise could easily be done for other countries within Sub-Saharan Africa, using relevant data. This will indeed be a useful exercise since most countries within the region are commodity dependent.

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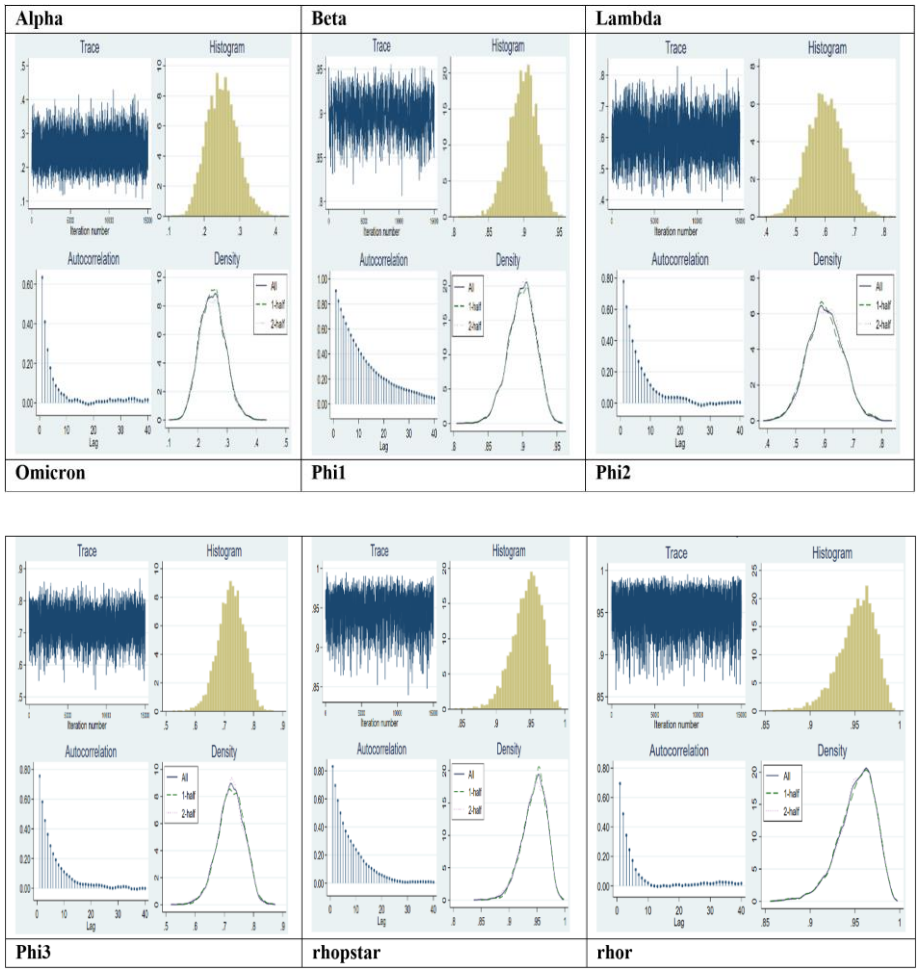
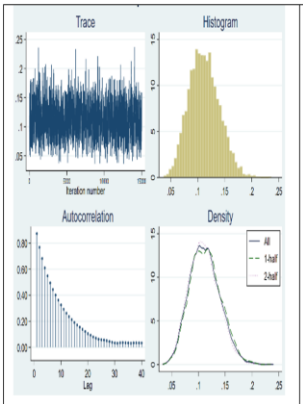
APPENDIX
APPENDIX A: MODEL WITH FINANCIAL FRICTIONS

A1. Convergence Diagnostics: Bayesian DSGE model for a small open economy with financial frictions





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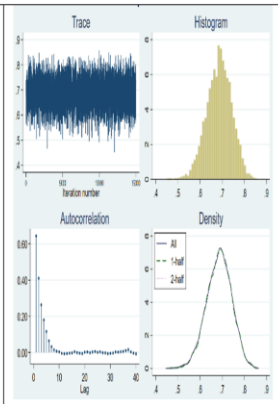

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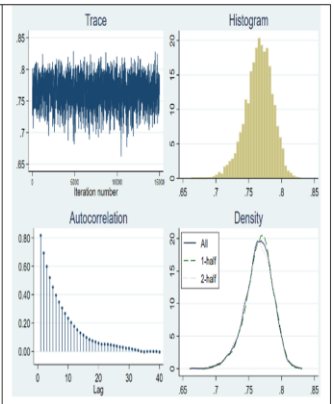

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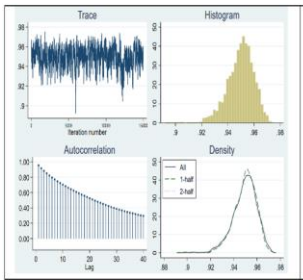

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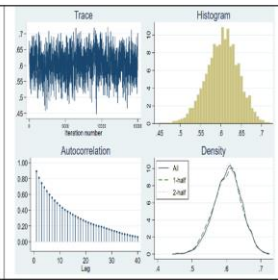

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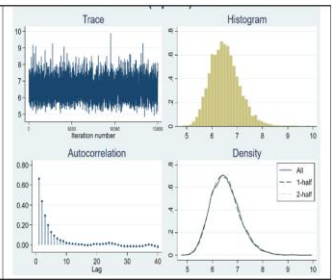

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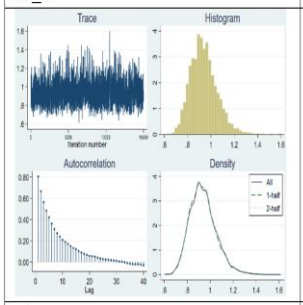

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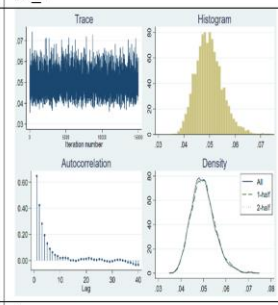

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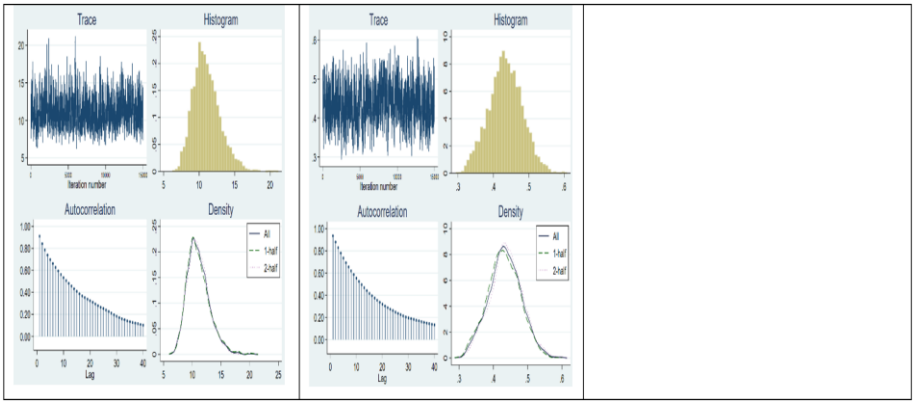
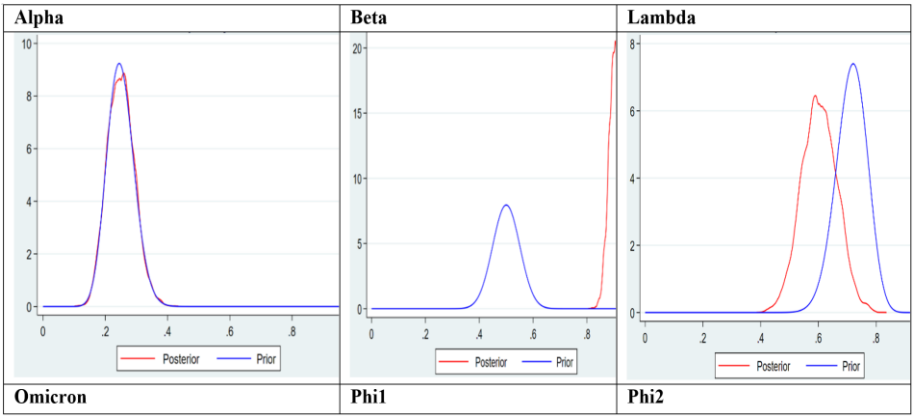
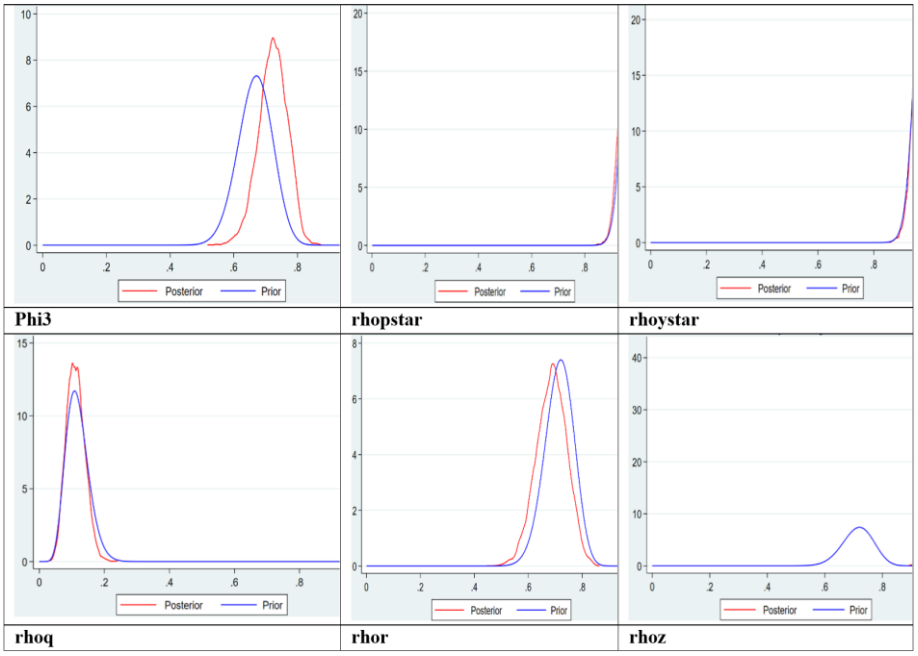


A2. Density Graphs: Bayesian DSGE model for a small open economy with financial frictions

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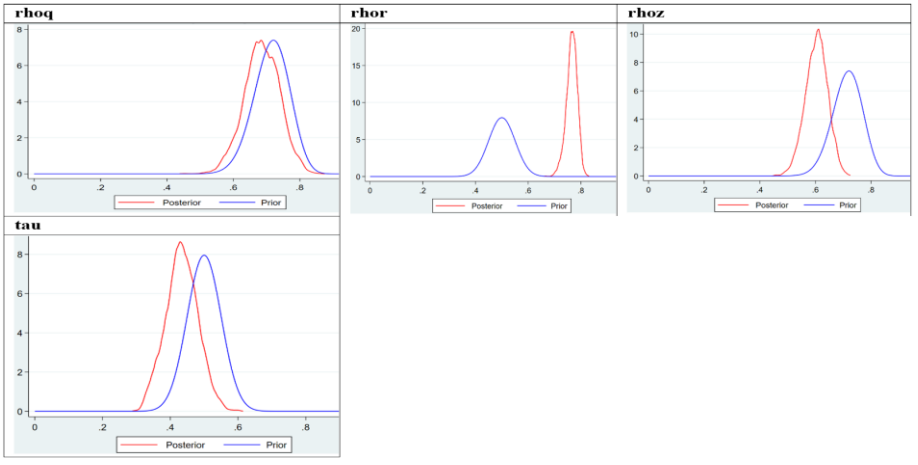
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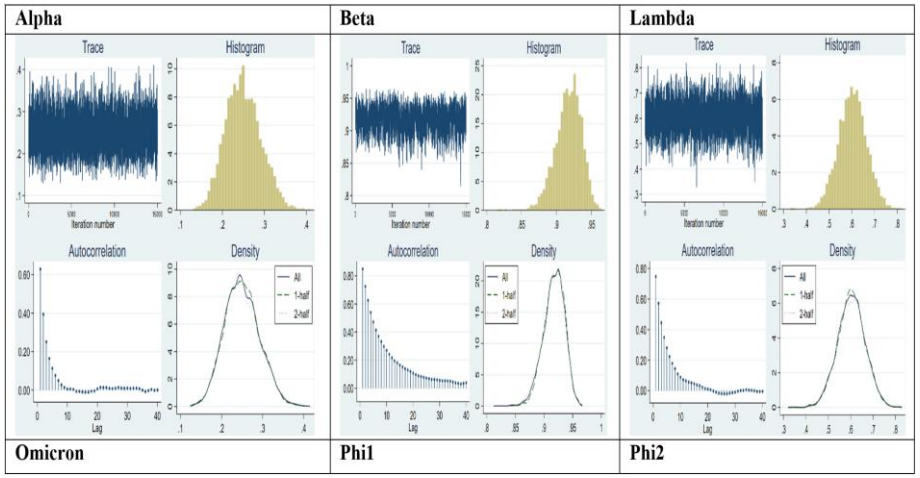
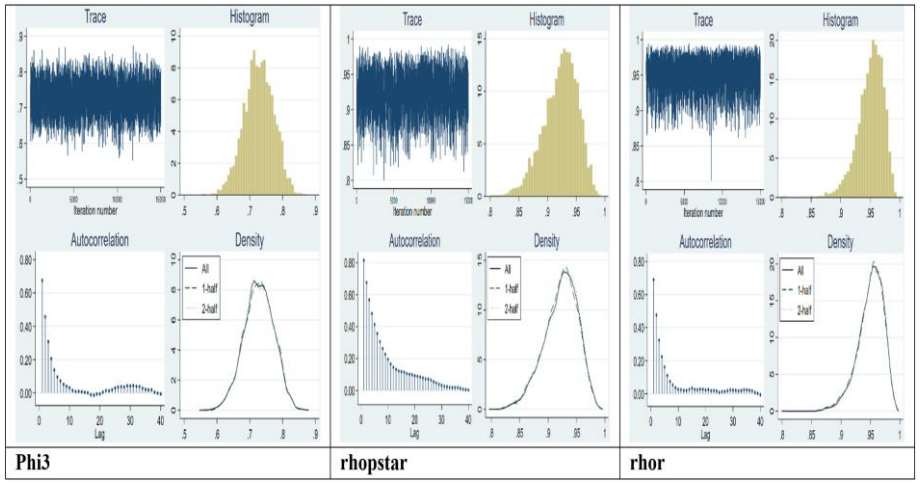
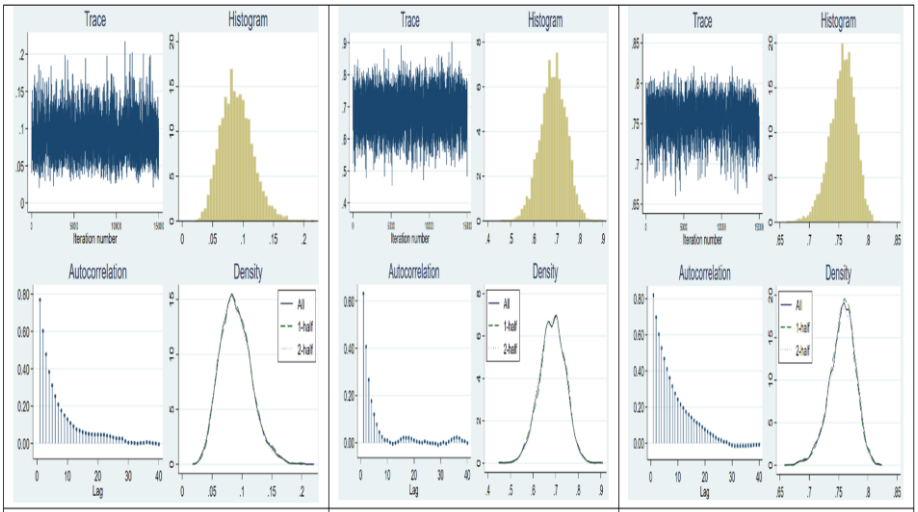
APPENDIX B: MODEL WITHOUT FINANCIAL FRICTIONS

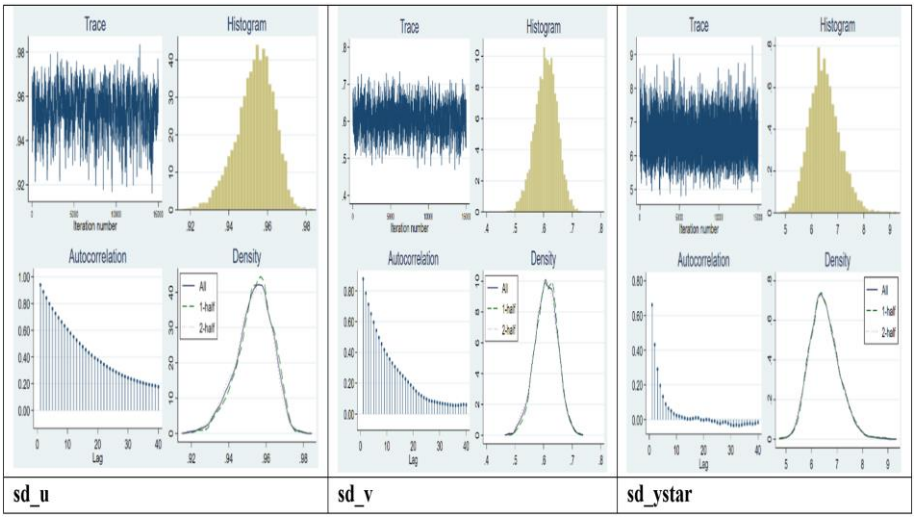
B1. Convergence Diagnostics: Bayesian DSGE model for a small open economy without financial frictions







rhoystar | rhoz | sd_pstar



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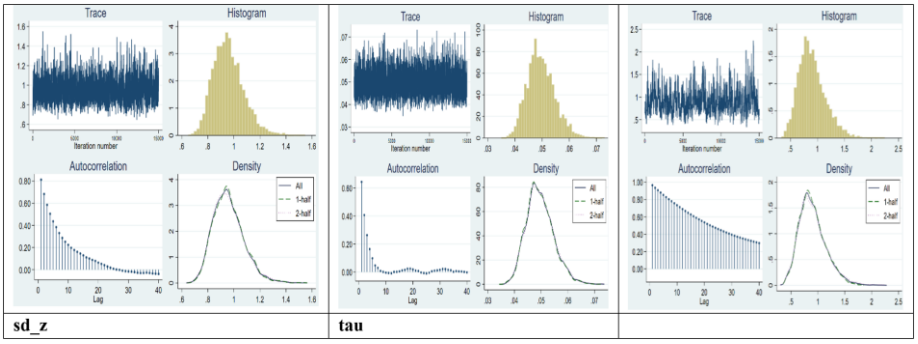
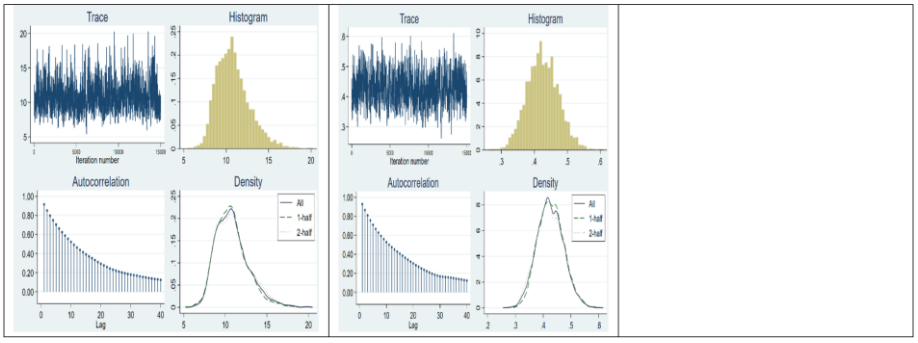
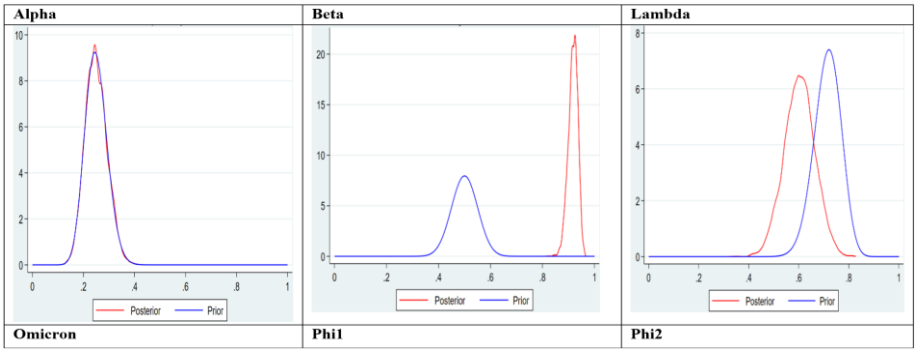
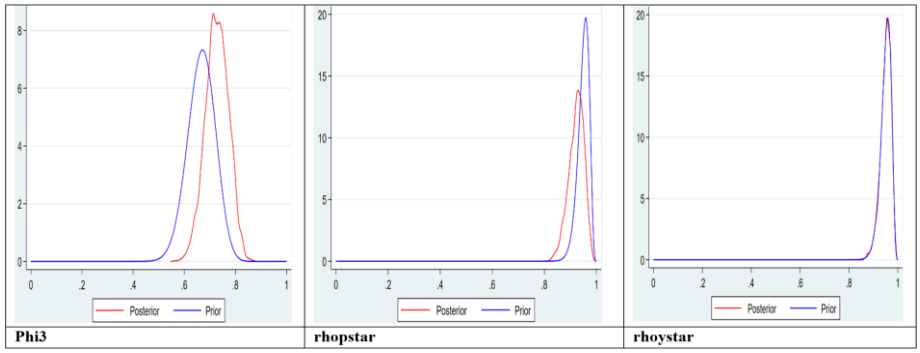




B2. Density Graphs: Bayesian DSGE model for a small open economy without financial frictions





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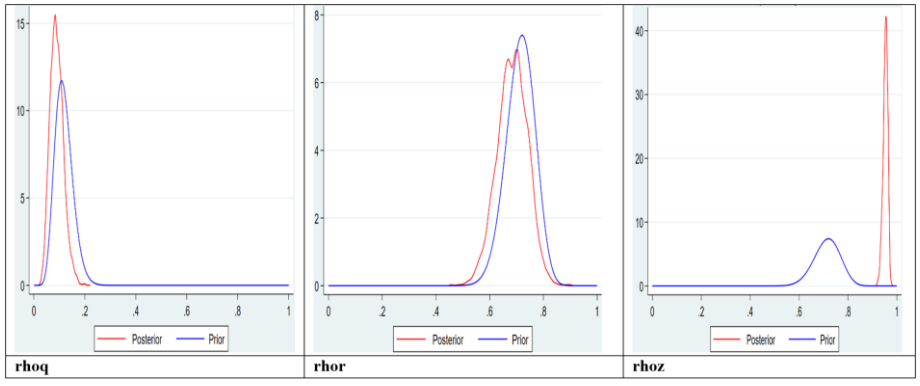
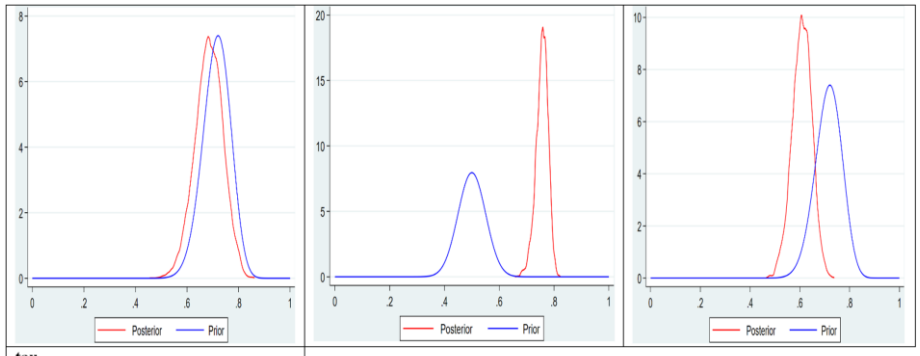


rhoq | rhor | rhoz



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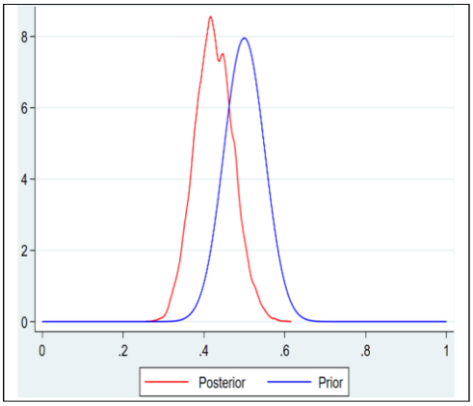
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FINANCIAL FRICTIONS AND MONETARY POLICY REACTION IN SIERRA LEONE: A BAYESIAN DSGE APPROACH

Emerson Abraham Jackson[1] and Mohamed Samba Barrie[2]

Abstract

This paper uses a Bayesian estimation approach to examine the behavior of the Sierra Leone's economy by creating a small-open economy DSGE model that includes financial frictions. The study utilises a New Keynesian framework to examine the actions of diverse economic agents, such as households, enterprises, the monetary authority, and the financial sector. The primary aim is to assess the model's realism in representing the monetary policy transmission in Sierra Leone. The results indicate that monetary policy shocks are temporary and that the Bank of Sierra Leone ought to increase policy rates in reaction to elevated inflation. Nonetheless, there are deficiencies in the transmission of monetary policy, rendering it ineffectual in regulating inflation or stimulating productivity. Depreciation of the exchange rate results in a significant transmission of imported inflation. The paper indicates that financial frictions do not affect output, inflation, or the monetary policy rate. The findings offer valuable insights for policymakers and underscore the advantages and constraints of monetary policy in regulating inflation and stimulating output in Sierra Leone.

Keywords: *Financial Frictions, Bayesian DSGE Model, Open economy, Sierra Leone.*

JEL Classification: *E12, E32, E52, G01*

1.0 Introduction

The notion of financial frictions and their possible influence on global economic business cycle variations has received considerable scrutiny following the financial crisis of 2007-09. A plethora of studies utilising Dynamic Stochastic General

[1] Special Economic Assistant (SEA), Governor's Office, Bank of Sierra Leone.

[2] Research Economist, Macroeconomic Research Division, Research and Statistics Department, Bank of Sierra Leone

Equilibrium (DSGE) modelling has arisen to analyse the efficacy of financial systems (Gerali et al., 2010; Merola, 2015; Atenga et al., 2021; Lyu et al., 2023). Numerous research works sought to elucidate the origins of financial frictions (Gerali et al., 2010), whereas others, such Brunnermeir and Pedersen (2009), examined the impact of liquidity crises associated with elevated Non-Performing Loans (NPLs). Bernanke (2012) and his associates (Bernanke, Gertler, & Gilchrist, 1999) have been essential in elucidating the micro-foundations of financial frictions linked to crises and examining the central bank's reaction to issues of monetary and financial stability.

Financial frictions, linked to elevated NPLs, reflect inefficiencies within the financial system that disrupt credit flows, heighten systemic vulnerabilities, and amplify the adverse effects of economic shocks (Brunnermeir and Pedersen, 2009). Financial friction is becoming a growing concern for the stability of the global economy as evidenced by the recent empirical DSGE model outputs (Atenga et al., 2021). The creation of models that incorporate incidents of shocks due to imperfections in the financial system has been instrumental in increasing knowledge and understanding of the underlying sources and causes of financial frictions in an economic system (Atenga et al., 2021; Finocchiaro & Grodeka, 2018; Gerali et al., 2010). The model developed by Bernanke, Gertler, & Gilchrist (1999), which combined nominal rigidities (also linked to borrowers and lenders) has improved our understanding of how the credit market can significantly account for shocks in the economy by incorporating financial frictions. This model indicates that an unforeseen rise in the nominal interest rate would diminish capital demand, resulting in a decline in price. Numerous studies have illustrated that disturbances in the financial sector significantly influence the transmission of monetary policy to the real economy, hence, underscoring the effect of financial frictions on monetary policy outcomes (Christensen and Dib, 2008; Christiano, Motto, and Rostagno, 2010).

Sierra Leone, as a small-open economy, is particularly vulnerable to external shocks since the real sector cannot satisfy the demands of economic agents for essential commodities and services (Warburton and Jackson, 2020). Historical research indicates that the financial system in Sierra Leone has encountered multiple frictions that significantly impact price and financial stability. Many empirical studies have

highlighted issues such as poor corporate governance, weak compliance, and inadequacies in financial regulations that contribute to systemic failure in the banking system (Kargbo & Adamu, 2009; Decker, 2012; Johnson, 2012; Balma & Ncube, 2015; Jackson & Tamuke, 2022). This study examines the impact of financial frictions on the financial system and the monetary policy authority's response to stabilize the economy, despite the scarcity of literature on this topic within the context of the Sierra Leonean economy.

This study employed a DSGE modelling approach to elucidate the research topic, viewing the economy as a heterogeneous system composed of various agents, including households, firms, government, and the central bank (Barrie and Jackson, 2022). The paper contributes in two ways. Primarily, it seeks to assess the effects of financial friction shocks on a small-open economy such as Sierra Leone. A full DSGE model with financial system frictions will be utilized to accomplish this. Secondly, the study will analyse the efficacy of monetary policy transmission in addressing shocks and their spillover effects on the overall macroeconomy. A DSGE model with Bayesian priors will be used to uncover the role of the monetary authority in responding to shocks and its potential impact on inducing inflationary pressure in the domestic economy. The motivation behind the study is strengthened using own country data that is informed by DSGE theory and its application to financial frictions.

The rest of the paper is organized as follows: Section 2 focuses on a literature review, both theoretical and empirical. Section 3 presents the structure of a DSGE model specifically tailored to the Sierra Leone's economy. Section 4 presents the estimated model parameters, which allow for demonstrating the impact of shocks on the model blocks. Section 5 analyses impulse response shocks, both financial and non-financial. Finally, Section 6 concludes by offering recommendations to support Bank of Sierra Leone's (BSL's) goals of price and financial stability.

2.0 Literature Review

This section is divided into two sub-sections: a theoretical review and an empirical review, both aimed at gaining an understanding of the impact of financial frictions on the stability of an economy.

2.1. Theoretical Literature

The theoretical review part concentrates on two significant theories of financial frictions pertinent to the examination of financial frictions and monetary policy responses in Sierra Leone from a DSGE perspective. These are the Diamond-Dybvig Model and Private and Public Liquidity Provision Theory

The Diamond-Dybvig Model, created by Douglas Diamond and Philip Dybvig in 1983, is a foundational study in financial economics that examines the mechanics of bank runs and the need for deposit insurance. This significant approach differentiates between sequential service, wherein depositors can access their accounts only at designated periods, and contingent service, which permits on-demand withdrawals. It clarifies how uncertainty and differing liquidity requirements among depositors can instigate bank runs, even in solvent institutions, because of a coordination issue. The approach presents deposit insurance, a government-backed assurance, as a mechanism to prevent bank runs by guaranteeing the safety of deposits during insolvency. Nonetheless, it highlights the moral hazard conundrum, in which insured banks may engage in more hazardous conduct. The Diamond-Dybvig Model has significantly influenced discussions on financial regulation, emphasizing the trade-offs between liquidity provision and the stability of the banking system. It supports our understanding of deposit insurance and the necessity for judicious banking rules to prevent systemic financial disasters.

In their 1998 work "Private and Public Supply of Liquidity," Bengt Holmström and Jean Tirole explore the complex dynamics of liquidity provision in financial markets. Their study highlights the dual roles of private and governmental institutions in facilitating the efficient operation of these markets. They differentiate between "asset liquidity" and "market liquidity," emphasizing the importance of private entities, including financial institutions and market players, in effectively aligning buyers and sellers. The study examines the influence of informational frictions, including adverse selection and moral hazard, on liquidity provision, and investigates the essential function of public institutions, such as central banks, in supplying liquidity during periods of market distress and financial crises. Furthermore, it analyses the notion of the "lender of last resort" and the circumstances that justify public interventions.

Holmström and Tirole's insights have significant consequences for financial regulation and market design, elucidating the intricate balance between market forces and government interventions in preserving liquidity and preventing financial instability.

The significance of theories about financial frictions and monetary policy responses in the context of Sierra Leone is clear and substantial. Sierra Leone, analogous to other developing nations, encounters distinct obstacles inside its financial sector and monetary policy administration, rendering these theories especially relevant. The notion of financial frictions, illustrated by the Diamond-Dybvig Model, is particularly pertinent. The banking sector in Sierra Leone is potentially vulnerable to runs owing to diminished depositor confidence and economic instability. Comprehending the mechanics of bank runs and the significance of deposit insurance is essential for policymakers in Sierra Leone to ensure financial stability and protect depositors. Secondly, the notion of private and public liquidity provision, as articulated in the Holmström and Tirole study, is pertinent to the situation of Sierra Leone. The nation's financial intermediaries are essential in promoting economic growth by directing cash to borrowers. The existence of moral hazard issues highlights the necessity for robust regulation and oversight to reconcile liquidity availability with risk management. In conclusion, these theories offer significant insights into the difficulties encountered by Sierra Leone in addressing financial frictions and developing effective monetary policy solutions. They emphasize the necessity of establishing stringent financial laws, such as deposit insurance, and formulating policies that balance the promotion of liquidity provision with the reduction of moral hazard hazards. Furthermore, examining these concerns within a DSGE framework enables policymakers to foresee and address the intricate interconnections between financial frictions and external economic shocks in a small-open economy such as Sierra Leone. These theories offer a significant theoretical basis for empirical research within a DSGE framework, consistent with the study's aims of examining financial frictions and monetary policy responses in Sierra Leone.

2.2. Empirical Literature

Considering the preliminary considerations, our research enhances the expanding empirical literature on financial frictions by employing a DSGE framework tailored to

the Sierra Leonean economy. Our aim is to enhance the existing knowledge with a focus on the central bank and to examine the impact of relevant shocks on financial frictions.

More recently, Alpanda and Simsek (2022), the focus was on examining how financial frictions influence the dynamics of an economy using a DSGE model. Their research indicates that financial frictions can profoundly affect economic stability, introducing considerable instability into the system. Furthermore, they discovered that the existence of these frictions might result in significant changes in the efficacy and dissemination of monetary policy. This indicates that central banks and policymakers must meticulously evaluate the ramifications of financial frictions when devising and executing monetary policy plans, as these frictions can significantly influence the economic environment and the results of policy initiatives.

An empirical study conducted by Atenga et al. (2021) evaluated the influence of financial frictions on business cycles across many major economies, including Canada, the Euro Area, the U.K., and the U.S., specifically during the global financial crisis of 2007-09. The researchers utilized a DSGE model created by Merola in 2015 for their analysis. The study intended to elucidate the underlying dynamics of macroeconomic fluctuations during this important period by examining multiple model features, including posterior distributions, variance decomposition, and history decomposition. The study's findings revealed an increased impact of financial frictions and shocks on the examined economies, highlighting the importance of financial factors in exacerbating and disseminating economic disturbances during the global financial crisis. This study enhances our comprehension of the intricate relationship between financial frictions and macroeconomic volatility following a significant financial crisis.

Chéron & Straub (2021) examined the influence of financial frictions on the transmission of macroeconomic shocks, employing a DSGE model. Their research demonstrates that financial frictions can exacerbate the effects of macroeconomic shocks, heightening the ensuing economic disturbances. The research indicates that monetary policy can effectively mitigate these amplifications, underscoring the

significance of central bank interventions in regulating financial frictions and stabilizing the economy during periods of turbulence.

In a distinct study, Armenter, Collard, and Fanelli (2021) investigated the impact of financial frictions on the dynamics of the term structure of interest rates within a DSGE model. Their findings indicate that financial frictions can cause significant volatility in the term structure of interest rates, potentially resulting in variations in borrowing costs across various maturities. The analysis indicates that the efficacy of monetary policy measures may depend on the precise type and characteristics of financial frictions, underscoring the intricate relationship among financial market circumstances, interest rates, and policy interventions. Their study provides essential insights into the complexities of financial frictions and their effects on macroeconomic stability and financial markets.

Baldi, Marzban, and Rubaszek (2020) investigated the influence of financial frictions on the transmission of monetary policy using a DSGE model. Their study demonstrates that financial frictions can alter the effects of monetary policy on the whole economy. The degree to which these impacts are modified is contingent upon the characteristics and type of the financial frictions in question. This discovery highlights the need of acknowledging the diversity and intricacy of financial market frictions and their capacity to affect the effectiveness of central bank policy. It underscores the necessity for policymakers to consider the complexities of financial market conditions when devising and executing monetary policy measures, as these conditions can profoundly influence the results of policy interventions and the broader macroeconomic environment.

Armenter, Collard, and Fanelli (2019) conducted a study examining the influence of financial frictions on economic dynamics through a DSGE model. Their findings indicated that financial frictions can significantly induce volatility in macroeconomic indicators, affecting the overall economic environment. Their findings emphasized that monetary policy can effectively mitigate the negative impacts of financial frictions, underscoring the crucial role of central bank interventions in addressing financial market issues and fostering macroeconomic stability.

In the same year, a separate study by Baldi, Marzban, and Rubaszek (2019) investigated the influence of financial frictions, concentrating specifically on the transmission of monetary policy within a DSGE model. Their research revealed that financial frictions can modify the transmission mechanism of monetary policy, affecting the influence of interest rate adjustments and other policy instruments on the broader economy. Moreover, the study highlighted that the nature and attributes of these financial frictions significantly influence the transmission mechanism. This conclusion highlights the intricacy of financial market dynamics and indicates that the efficacy of monetary policy tools depends on the financial frictions involved. Policymakers must consider these elements while formulating and executing monetary policy measures to get their desired economic objectives.

Tufail and Ahmad (2018) conducted a study centred on developing economies, notably Pakistan, analyzing financial frictions and the optimal policy response to economic shocks. The study investigated three key areas regarding the role of financial frictions in Pakistan: first, it compared a standard New Keynesian DSGE model calibrated with financial frictions to a scenario in which the financial structure is deemed irrelevant in observing the behavior of the prevailing macroeconomic situation. Second, the study evaluated the extent of diverse repercussions and the dissemination of multiple demand and supply-side shocks amid financial frictions. Third, it empirically validated the effects of various shocks on optimal policy. The study's policy implications highlight its significance for inflation results, production, and consumption, although it did not include the instability caused by monetary and financial shocks.

Chéron and Straub (2017) performed a study on the transmission of macroeconomic shocks within a DSGE model with financial frictions. The authors discovered that financial frictions can exacerbate the impacts of macroeconomic shocks, and that monetary policy can serve as an effective instrument for alleviating these exacerbations. These frictions, which may appear as interruptions in credit markets, challenges in obtaining finance, or fluctuations in borrowing prices for consumers and enterprises, exacerbate the economic consequences of shocks. Nonetheless, their research highlights the efficacy of monetary policy as a mechanism to mitigate these

exacerbating effects. Central banks can affect credit availability, borrowing costs, and total financial system liquidity through tools such as interest rates, thereby alleviating the negative effects of financial frictions and fostering economic stability during shocks.

The empirical literature on financial frictions is crucial in emphasizing the importance of our work in the context of Sierra Leone. These studies, primarily undertaken in industrialized and certain emerging nations, highlight the critical impact of financial frictions on inducing economic instability and altering the efficacy of monetary policy. They emphasize that financial frictions can induce significant variations in essential macroeconomic indicators, highlighting the effects of different shocks. This literature underscores the capacity of monetary policy to mitigate the detrimental effects of these frictions.

Nonetheless, a significant research deficit exists in the analysis of financial frictions and central bank policy responses in small-open economies such as Sierra Leone. Considering the distinct attributes and susceptibilities of different economies, our research's sole emphasis on Sierra Leone and the utilization of a DSGE model may yield significant insights. It seeks to highlight the essential function of the central bank in mitigating financial frictions and their implications for economic stability, a facet frequently neglected in the current research. This paper aims to address this research vacuum by offering a context-specific analysis focused on Sierra Leone, examining the effects of financial frictions on price and financial stability—issues of critical importance for BSL.

3.0 Model Specification

In this section, we present a small-scale open-economy DSGE model for Sierra Leone. The model begins with a continuum of infinitely-lived households indexed as $i \, \epsilon [0; 1]$, which make consumption and savings decisions and set wages in a staggered fashion. In contrast to the standard New Keynesian model, we assume that monopolistically competitive firms are price makers in the goods market, but they face nominal rigidities introduced by Calvo's 1983 price setting. The monetary authority controls nominal interest rates and is concerned with both price and GDP growth and follows

a Taylor rule. We extend the Keynesian DSGE framework for a small-open economy with financial frictions, where households consume and invest in baskets of domestically produced and imported goods, and imported goods are allowed to enter both aggregate consumption and investment to match the joint fluctuations in both imports and consumption. We model an economy in which the growth rate of the trade-weight exchange rate is exogenous and affected by inflationary pressure. We incorporate interest rate spreads in the financial frictions specification to allow for financial instability to pass through to inflation, exchange rate, and productivity, and ultimately, the central bank policy action to implement an effective policy stance. Lastly, we describe the linkages among households, firms, the external sector, central bank, and the banking system, which intuitively explain the development of financial frictions[3].

3.1 Households

In addition to accumulating physical capital and holding cash, households can save on domestic and foreign bonds. The choice between domestic and foreign bond holdings balances into an arbitrage condition, invariably pinning down expected exchange rate changes (i.e., an uncovered interest rate parity condition). The output gap is specified in the output gap equation below, which is an Euler equation[4] stating the inter-temporal first-order condition for a dynamic choice problem facing the representative household. The output gap is specified as a function of future expected output interest rate, inflation, and government policy shock.

$$x_t = E_t(x_{t+1}) - \{r_t - E_t(p_{t+1}) - g_t\} \quad (1)$$

The output gap is modelled as an unobserved control variable, where: r_t is the interest rate and it is modelled as an observed control variable, while p_t is the inflation rate is modelled as an observed control variable. The shock process here evolves following the specification

$$g_{t+1} = \rho_g g_t + \xi_{t+1} \quad \text{Productivity shock} \quad (2)$$

[3] A detailed presentation of the model is provided in the working paper version of Adolfson et al. (2005).

[4] It describes the evolution of economic variables along an optimal path.

Also defined as the productivity shock. The variable g_t is a first-order autoregressive state variable.

3.2 Firms

There is a continuum of monopolistic firms $i \epsilon [0;1]$ that choose their price P^*. Among these firms, a fraction of θP is not allowed to set the price, then the price remains the same such that $P_t^* = P_{t-j}$. For the share $1 - \theta P$ of firms allowed to reset their price, each firm maximizes the expected sum of profits:

$$\max_{P_{t(j)}^*} \sum_{t=0}^{+\infty} (\beta\theta p)^{\tau} (P_t^*)(j) - MC_{t+\tau}(j) Y_{t+\tau}(j), \quad (3)$$

Where Y is total output/income whilst MC is the marginal cost for a typical household or firm. Under the demand constraint from final goods, the first-order conditions, combined with the aggregate price equation and taken in logs give rise to the New Keynesian Phillips Curve.

Here, it is assumed that the final domestic good is a composite of a continuum of i differentiated goods, each supplied by a different firm. Since the central bank has a time-varying inflation target of p_t in the model, we allow for interest rate inertia to the current inflation target, but also the inflation expectation term in the Phillips curve. The process for the first-order condition of the profit maximization problem yields the following augmented log-linearized Phillips curve:

$$p_t = \rho_p L p_t + \left(1 - \rho_p\right)[\beta E_t(p_{t+1}) + \kappa x_t + \phi e s_t] \quad (4)$$

Where: p_t denotes log deviation from steady-state and denotes inflation in the domestic sector. We now turn to the import and export sectors. There is a continuum of importing consumption and investment firms, which buys a homogeneous good at a price of P_t^* in the world market and converts it into a differentiated good through a brand naming technology. The exporting firms buy the (homogeneous) domestic final good at a price of P_t^d and turn this into a differentiated export good through the same type of brand naming technology. The nominal marginal cost of the importing and exporting firms is thus $S_t P_t^*$ and P_t^d / S_t respectively. Where: S_t is the nominal exchange rate (domestic currency per unit of foreign currency). The differentiated

imported and exported goods are subsequently aggregated by import for consumption, import for investment, and an export packer – this means that the final import consumption, import investment, and export good should constitute a Constant Elasticity of Substitution (CES) composite.

To allow for short-run incomplete exchange rate pass-through to import and export prices, we introduce nominal rigidities at the local currency price, following Smets & Wouters (2002)[5]. The price-setting problems of the importing and exporting firms are completely analogous to those of the domestic firms. In total, there are two specific Phillips curve relations determining inflation in the domestic, import consumption, import investment, and export sectors, all having the same structure as illustrated in Eq. (3). Recall the canonical New Keynesian DSGE model of inflation (p_t), output gap (x_t) and the interest rate (r_t) includes an exogenous (observed=domestic exchange rate=foreign exchange rate) variable. As such we have further extended the model by adding an AR (1) for the unobserved state variable(est) and an equation linking the unobserved (est) to the observed (e_t), thereby specifying how the unobserved state (est) is transformed into the observed control variable (e_t). Recalling that all the observed variables in a DSGE model must be modelled as endogenous control variables. This requirement implies that there is no reduced form for the endogenous variables as a function of observed exogenous variables – indicating from the theory that exogenous variables should be modelled. Mechanically, the solution is to define a control variable that is equal to a state variable that models the exogenous process. We clarify this issue by allowing for the above identity to hold then

$$e_t = es_t \tag{5}$$

Where: e_t is the growth rate of the exchange rate, which we have modelled as an observed exogenous variable. Note that we have, therefore, modelled an economy in which the growth rate of the trade-weighted exchange rate is exogenous and in which it affects inflation. Henceforth, we would refer to the trade-weighted exchange rate as

[5] Since there are neither any distribution costs in the import and export sectors nor is there any endogenous pricing to market behavior among firms, pass-through is complete in the absence of nominal rigidities.

the exchange rate. Note that the evolution or transmission of the exchange rate *est* shock as a state variable with an AR (1) process is defined as follows:

$$es_{t+1} = \rho_{es} es_t + v_{t+1} \quad (6)$$

This assumption is informed by our knowledge of the Sierra Leonean economy, where the prevailing domestic exchange rate is largely taken as given and highly influenced by external factors and the informal sector. This is because the fundamentals of the domestic economy are not strong enough to influence the path of the exchange rate

3.3 Central Bank

The central bank follows a generalized Taylor rule in setting interest rates in the short run. As such, we approximate the behaviour of the central bank by following Smets & Wouters (2002) approach - where the central bank is assumed to adjust the short-term interest rate in response to the CPI inflation rate, the inflation target, the output gap (measured as actual minus trend output)[6].

$$r_t = \frac{1}{\psi} p_t + u_t \quad \text{(Basic Taylor Rule)} \quad (7)$$

Observe that implicit in the basic Taylor rule is the inflation specification as such making the interest rate a reaction function to inflation. Recalling also that the price equation is a function of the exchange rate as we had specified earlier in Equation 4. Moreover, it is important to note that, unlike the standard DSGE model without financial frictions, the DSGE model with a financial accelerator mechanism incorporates the spread shock and the net worth shock. To see how this is linked to the interest rate let us restate the Taylor rule. Equation 7 is an expression for the safe interest rate, which is akin to the Taylor rule. The Taylor rule is used to predict or guide how central banks should alter interest rates due to changes in events in the economy. The Taylor rule recommends that the central bank should raise interest rates when inflation or GDP growth rates are higher than desired. However, we augment the Taylor rule with an interest rate lag effect and specify it as shown below:

[6] An alternative specification is to define the output target in terms of the output level that would have prevailed in the absence of nominal rigidities as in Smets and Wouters (2002). This model's consistent output gap would probably come???

$$r_t = \rho_r Lr_t + \frac{1-\rho_r}{\psi} p_t + u_t \quad (8)$$

Moreover, the lagged interest rate is also a function of the price level. As such we specify the monetary policy shock as following an AR (1) process as specified below:

$$u_{t+1} = \rho_u u_t + \epsilon_{t+1}; \quad (9)$$

The variable u_t is a first-order autoregressive state variable for monetary policy shock. The structural shock processes in the model are given in log-linearized form by the univariate representation.

3.4 Financial Frictions

We also extend the model to account for financial frictions, which in simple words imply wedges between the cost of capital and the return that investors earn from the capital. They can be measured as a gap between the returns earned by savers and the cost of accessing credit. In practice, financial frictions are included in standard DSGE models, which build on the work of Bernanke et al. (1999), Christiano et al. (2014), and Del Negro et al. (2015). The assumption is that entrepreneurs borrow funds from the banks and invest those to acquire physical capital. However, entrepreneurs are subject to idiosyncratic shocks, which affect their ability to manage capital, and therefore their ability to repay their bank loans. To protect themselves against the entrepreneurs' default risk, banks charge a spread over the deposit rate when lending money. The simplest of such models place a wedge between two interest rates: the safe interest rate set by the central bank (r_t) and the market interest rate (i_t) used by consumers and producers as shown in Equation 10

$$i_t = \theta r_t + sp_t \quad (10)$$

Equation 11 describes the interest spread, which specifies financial frictions as the difference between the monetary policy rate and commercial bank or fund manager's rate. A large realization of sp_t is represented by a large interest rate spread, indicating financial distress/frictions. We generate the structural shock processes which follow an AR(1) procedure shown in Equation 11.

$$sp_{t+1} = \rho_{sp} sp_t + \eta_{t+1} \quad (11)$$

The state variable sp_t is the current interest spread measuring financial distress whilst η_{t+1} represents a future unanticipated financial shock to the entrepreneurs/firms' net worth and the banking system. Any negative impact on the entrepreneurs' or firms' net worth tends to affect the ability to debt service and therefore increases non-performing loans within the commercial banking system, which essentially adds to financial frictions in the economy.

3.5 The External Sector

In a classic open economy model, in addition to interest rates, the exchange rate and terms of trade are key, among other issues such as home versus foreign goods, tradable versus non-tradable, and capital mobility. With these extensions, we can accommodate additional (external) shocks in our estimable DSGE model such as commodity shock, trade shock, productivity shock, and financial friction shock among others. We extend the canonical New Keynesian DSGE model of inflation p_t, the output gap x_t, and the interest rate r_t to include an exogenous (observed) variable in the Philips curve equation in (4) above. Recall that we extend the model by adding an AR(1) process for the unobserved state variable est and an equation linking the unobserved est to the observed e_t see equation 6, where e_t is the growth rate of the exchange rate, which we have modelled as an observed exogenous variable. Therefore, we have modelled an economy in which the growth rate of the trade-weighted exchange rate is exogenous and affects inflation. Henceforth, we call the trade-weighted exchange rate just the exchange rate.

3.6 Shocks

The structural shock processes in our extended model are given in a log-linearized form by the univariate representation. Where a first-order autoregressive process AR (1) is the standard approximation to all the exogenous variables.

3.7 Data Sources and Description

To estimate the model, we use quarterly data (2011Q1 – 2020Q4) sourced from the Bank of Sierra Leone. The variables for the study are GDP deflator, monetary policy

rate, commercial bank lending rate, the growth rate of the exchange rate, and growth rate of the nominal effective exchange rate and inflation rate.

3.8 Estimation Method & Calibration of Priors

In the empirical literature, there are numerous strategies used to determine the parameters of new Keynesian DSGE models. This study uses a Bayesian estimation approach, which combines both calibration and estimation of selected model parameters. According to Bergstrom (2001), priors can be gleaned from personal introspection to reflect strongly held beliefs about the validity of economic theories. Priors also reflect researchers' confidence about the likely location of the structural parameters of the model. In practice, priors were chosen based on observation, facts, and the existing empirical literature.

To perform the Bayesian estimation of the model, we need to specify priors for the parameters. Parameters in a DSGE model typically have economic interpretation. We use those interpretations to specify informative priors. The model has seven structural parameters ($\phi,\ \beta, \kappa, \theta, \psi,\ \rho_p, \rho_r$) and four standard deviation shock parameters ($\rho_u, \rho_g, \rho_{es}, \rho_{sp}$). The parameters of the beta distributions were chosen to affirm the weight of prior mass on theoretically appropriate values. We specify parameter Rho **(**ρ.) as inflation inertia in the price equation**.** It is expected to lie between 0 and 1, and for a small-open economy like Sierra Leone, it is probably in the higher end of the range. We use a prior beta distribution with parameters (30, 70). These parameters are consistent with studies done by Jackson and Tamuke (2022). Phi (ϕ) is the parameter for exchange rates on the price equation. We specified this with a prior beta distribution of (30, 70). This was informed by our knowledge of the impact of the exchange rate movement on inflation in Sierra Leone. Beta (β) is the parameter for inflation expectation in the price equation and is specified with a prior distribution (95, 5). Kappa (κ) is the parameter for the output gap in the price equation and it is specified with prior distributions of (30, 70). Theta (θ)is the parameter for the monetary policy rate in the interest spread equation, with a prior distribution of (80, 20). Psi (ψ) is the parameter for inflation in the monetary policy rule, with a prior distribution of (50, 50). Finally, Rho (r) is the parameter for interest inertia in the monetary policy rule (70, 30).

On the other hand, the autoregressive parameters Rho (u) is the monetary policy shock, with a beta prior distribution of (50, 50), whilst Rho (sp) is the financial frictions shock and assigned a prior distribution of (50, 50). However, since both perturbations represent financial system shocks, it can be assumed that there may be some level of relationship existing between them. Note that these are parameters defining the stochastic processes of these parameters. Therefore, Rho (g), the assigned productivity shock is specified with prior distributions of (75, 25), whilst Rho (ϵs) is the demand shock parameter and specified with prior distributions of (50, 50). Since both perturbations represent demand shocks, they can impact the equation of the Philips curve as already specified, which implies that there is a relationship between them.

3.9 Convergence Diagnostic

We checked for the convergence diagnostic of the model to determine whether there is convergence in the Markov Chain Monte Carlo (MCMC) simulation - such convergence indicates reliable parameter estimates (Fernandez-Villaverde and Guerron-Quintana, 2021). This then results in graphing the behaviour of individual parameters, as well as generating the effective sample size (ESS) summary statistics. To ensure that there is convergence efficiency, the trace plot should not exhibit a time trend and should be mean-reverting, and exhibit of constant variance and decaying autocorrelation. The density of the chain should not vary throughout the MCMC sample. In addition, the constant of the density distribution can be assessed by examining both the 1-half and 2-half density plots and must be symmetrical, or at worse, the differentials should be minimal. Significant differences in the density may invariably imply no convergence in the chain.

Attainment of low-level efficiency for the estimated linear DSGE model could also indicate convergence problems in the iteration processes. If such is the case, the recommendation is to estimate the model with block options - implying an imposition of restrictions/blocks on selected parameters to adjust for the observed high autocorrelation, which invariably may enhance the efficiency of the MCMC sampling. However, to properly identify the parameters (both structural and blocked state), an algorithm for the density functions command was written for all the parameters and immediately followed by a graphing of the diagnostic outputs to display comparison.

The structural parameters with the best performance should be restricted/blocked and followed by a re-estimation of the model. Simply put, identified parameters for the restricted / block options was informed by the behavior of the density functions.

4.0 Empirical Findings

4.1 Preliminary Analysis

The model summary, as referenced in Table 1 below, reports the prior and likelihood specifications, including the default inverse-gamma before the standard deviation of the shock. The output reports the burn-in length and MCMC sample size and information about the efficiency of the Metropolis-Hastings sampler. The overall acceptance rate is 41.9%, which is normally the value for models of this nature. The relatively high acceptance rate indicates that a large portion of the proposed MCMC iteration is accepted, with sufficiently high regions of the posterior probability. Whilst the sampling efficiencies range from 0.0992 to 0.2272, it is important to note that efficiency is directly linked to the autocorrelation of the MCMC draws, with higher efficiency indicating lower autocorrelation. The posterior mean for rhosp is 0.66, theta is 0.73, rhou is 0.57, rhor is 0.78, which seemingly are not identical to the prior means. The posterior mean for the rest of the parameters is almost identical. Overall, most of the parameters show little updating, indicating that the likelihood is uninformative along several dimensions of the model's parameter space. The posterior results for all parameters, except {rhosp}, {theta}, {rhou} and **{**rhor**}** are mainly driven by the priors. However, since the posteriors for some of the parameters manifest significant updating, we, therefore, checked the posterior diagnostics plots to determine which parameters need to be restricted/blocked (See Appendix 3).

From the estimated model in Table 1, the magnitude of the monetary policy, parameter (57.4%) in the steady-state long run is quite low, but not entirely surprising considering weak monetary policy transmission in Sierra Leone. Whilst the magnitude of productivity parameter has the highest impact in the long-run steady state at (77.6%), this is expected since Sierra Leone as a small-open economy depends largely on raw materials production (typically minerals), which account for a greater share of GDP. On the other hand, a demand parameter has the lowest impact in the long-run steady state at (52.4%). This is not surprising considering that Sierra Leone's economy

is dominated by economic agents with low incomes, with low demand-driven potential to induce high levels of production. Finally, a financial sector parameter has a magnitude of (65.8%) in the long-run, which surprisingly is higher than a monetary policy parameter. The implication is that, in the long run, the financial system plays a much more significant role in the expansion of output and the maximization of general welfare. All standard deviations are low and within a low and reasonable range, which means they are not distortionary to the model's stability.

After investigating effective sample sizes for each parameter in the estimated Bayesian model without block options (**see** Appendix 2), we observed that Effective Sample Sizes (ESS) for the estimated model, with block parameters, performed better than the model without the blocked parameters - this indicates that blocking improves the sampling efficiency of the model (shown in Table 2).

Based on Figure 1 below, the trace plot shows reasonable mixing, implying that all parameters exhibit Autocorrelation tail-off or decay at a moderate pace. While the density plot shows that the first and second-half densities do not substantially differ, a much better decaying of autocorrelation values is revealed compared to the model estimation without blocked parameters (see Appendices 1 and 4)

Table 1: Bayesian Estimation Results with blocked options

	Mean	Std. dev.	MCSE	Median	Equal-tailed	
					95% cred.	Interval
rhor	0.7835949	0.0376654	0.003712	0.7854651	0.7018533	0.8508351
psi	0.5496935	0.0453023	0.00292	0.5517569	0.4572508	0.6339941
theta	0.7315199	0.0484835	0.001101	0.7343399	0.6326788	0.8209356
rhop	0.2079591	0.032452	0.002159	0.2058095	0.1504237	0.2748733
Beta	0.9546248	0.0194235	0.001877	0.9573528	0.9110406	0.9855337
Kappa	0.3467494	0.0395534	0.002436	0.3457074	0.2739801	0.4302858
Phi	0.3100986	0.0460562	0.000966	0.3098658	0.2200655	0.4011811
rhou	0.5740353	0.0288702	0.001759	0.5740865	0.5172461	0.6283986
rhog	0.7755212	0.0334536	0.002647	0.7767339	0.7062917	0.8359467
rhoes	0.5243019	0.0441976	0.000947	0.525717	0.4354076	0.6090341
rhosp						
sd(e.u)	0.6582309	0.0447663	0.001401	0.6594133	0.5652389	0.7423243
sd(e.g)	2.960666	0.5895206	0.05062	2.908786	1.950352	4.296138
sd(e.es)	2.565157	0.603433	0.062783	2.488262	1.575094	3.926231
sd(e.sp	1.688917	0.1992753	0.004702	1.668829	1.359151	2.146878
rhoes	1.323758	0.2031606	0.006227	1.303207	0.9841857	1.775724
rhosp						

Notes: *The sample size of the above output ranged from 2011Q2 to 2020Q4, with 39 observations. The MCMC sample is 10,000 and Burn-in is 2,500. Where MCMC: Markov Chain Monte Carlo (MCMC) simulation. Whilst MCSE is the Mean Conditional Squared Error, which is a measure of the accuracy of the model's prediction.*

Rhor= is the parameter for interest inertia in the monetary policy rule

Psi= is the parameter for inflation in the monetary policy rule

Theta= is the parameter for the monetary policy rate in the interest spread equation

Rhop= inflation inertia in the price equation

Beta= is the parameter for inflation expectation in the price equation

Kappa= is the parameter for the output gap in the price equation

Phi= is the parameter for exchange rates on the price equation

Rhou= is the monetary policy shock parameter

Rhog= is the assigned productivity shock is specified

Rhoes= is the demand shock parameter

Rhosp= is the financial frictions shock parameter

Sd(e.u)= monetary policy shock
Sd(e.g)= productivity shock
Sd(e.es)= demand shock
Sd(e.sp)= financial shock

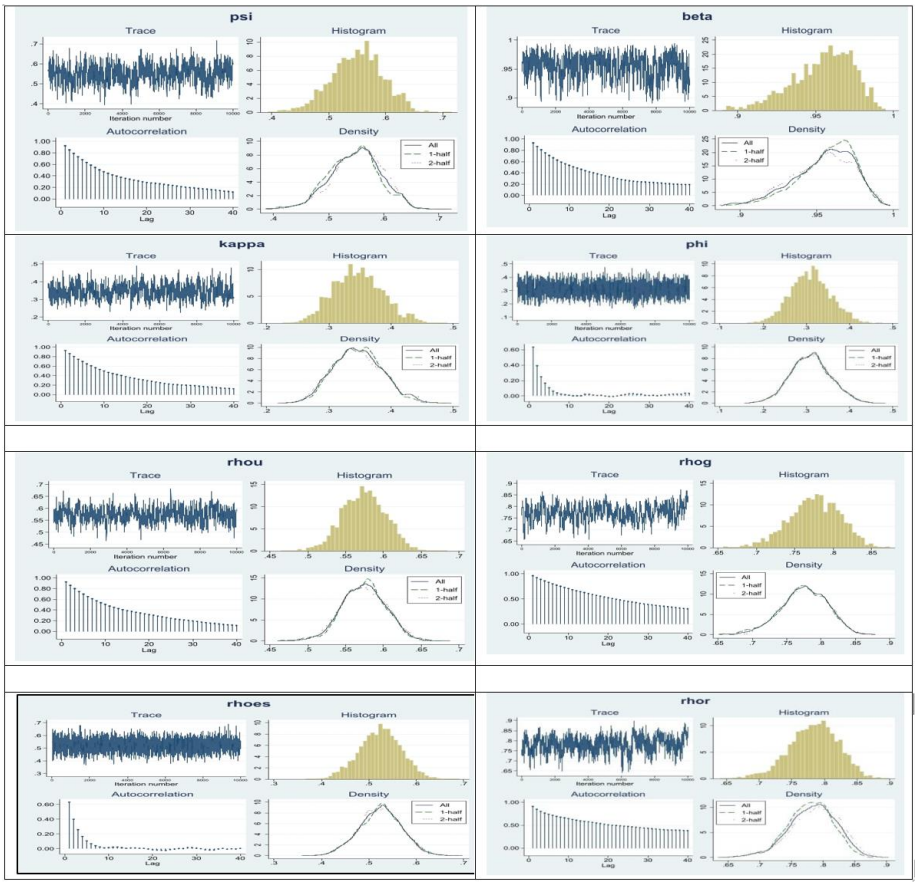
Table 2: Efficiency Summary Statistics

Efficiency Summary		**MCMC sample Size**		10,000
		Efficiency:	**Min**	0.009238
			Avg	0.07913
			Max	0.2272
	ESS	**Corr. time**		**Efficiency**
rhor	102.95	79.14		0.0103
psi	240.69	41.55		0.0241
Theta	1940.69	5.15		0.1941
rhop	226.02	44.24		0.0226
Beta	107.07	93.40		0.0107
Kappa	263.69	37.92		0.0264
Phi	2271.60	4.40		0.2272
Rhou	269.27	37.14		0.0269
Rhog	159.69	62.62		0.0160
Rhoes	2178.37	4.59		0.2178
Rhosp	1020.75	9.80		0.1021
Sd(e.u)	135.63	73.73		0.0136
Sd(e.g)	92.38	108.25		0.0092
Sd(e.es)	1795.85	5.57		0.1796
Sd(e.sp)	1064.42	9.39		0.1064

Rhor= is the parameter for interest inertia in the monetary policy rule
Psi= is the parameter for inflation in the monetary policy rule
Theta= is the parameter for the monetary policy rate in the interest spread equation
Rhop= inflation inertia in the price equation
Beta= is the parameter for inflation expectation in the price equation
Kappa= is the parameter for the output gap in the price equation
Phi= is the parameter for exchange rates on the price equation
Rhou= is the monetary policy shock parameter

Rhog= is the assigned productivity shock is specified
Rhoes= is the demand shock parameter
Rhosp= is the financial frictions shock parameter
Sd(e.u)= monetary policy shock
Sd(e.g)= productivity shock
Sd(e.es)= demand shock
Sd(e.sp)= financial shock

Figure 1: Blocked Post-Estimation Diagnostics for Model Parameters Plots



4.2 Impulse Response Functions

Figures 2-5 present the results of various structural shock analyses. By examining the impulse response functions, these figures offer a comprehensive understanding of the effects of monetary policy, demand, productivity, and financial shocks on key macroeconomic variables. These figures provide critical insights into the short-term and long-term consequences of these shocks and the potential impact they have on the economy. The results presented in these figures are thought-provoking and raise important questions about the role of monetary policy, demand, productivity, and financial stability in shaping the economic landscape. These figures serve as valuable tools for policy makers, economists, and other stakeholders in understanding the interplay between these factors and their impact on economic growth, inflation, and overall financial stability. They provide a deeper understanding of the complex relationships between these factors and the broader economy and offer guidance for informed policy decision making.

- **Monetary Policy Shock**

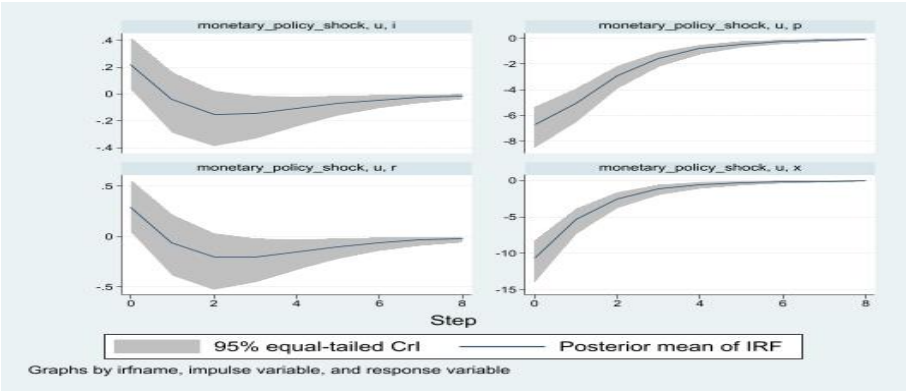
Figure 2 depicts the effects of a positive monetary policy shock on various macroeconomic variables in Sierra Leone. The monetary policy shock leads to a sharp increase in the domestic market interest rate in the immediate aftermath, but this increase starts to dissipate by the fourth quarter, and by fifth quarter it falls below the equilibrium level. The inflation rate experiences a steep decline but eventually returns to its pre-shock levels by the fifth quarter, which suggests that the effectiveness of monetary policy in controlling inflation is weak in the long run.

In the short run, the contraction in domestic output following a positive monetary policy shock reflects the immediate tightening of financial conditions. This sharp reduction in output signifies the economy's sensitivity to increased interest rates, which dampen consumption and investment activities. However, the gradual recovery of output, culminating in a return to pre-shock levels by the fifth quarter, underscores the transitory nature of the monetary policy shock and the economy’s inherent resilience. This recovery aligns with the classical dichotomy, which posits that monetary policy primarily influences nominal variables in the long run, with minimal sustained effects on real economic activities.

The observed dynamics in Figure 2 suggest that monetary policy shocks in Sierra Leone predominantly affect the economy through short-term channels. These include adjustments in aggregate demand and the corresponding immediate responses in inflation and output. The return to equilibrium by the fifth quarter indicates that the initial contraction in output is not structural but cyclical, allowing the economy to emerge from recessionary pressures.

The results emphasise the importance of proactive and adaptive monetary policy. While the findings affirm the transitory nature of monetary policy shocks, they also highlight the need for vigilance by policymakers in responding to evolving economic conditions. Rapid and precise adjustments to the monetary policy rate are essential to mitigate short-term downturns while fostering conditions for long-term stability. Figure 2 thus serves as a crucial tool for understanding the interplay between monetary interventions and macroeconomic stability, offering insights into crafting policies that balance short-term responsiveness with long-term objectives.

Figure 2: Response to Monetary Policy Shock



- **Demand Shock**

The analysis in Figure 3 demonstrates the dynamic effects of a positive demand shock on key macroeconomic variables in Sierra Leone. The immediate rise in the market interest rate reflects the economy's short-term adjustment to heightened demand

pressures. This increase remains steady until the second quarter, after which it declines continuously, converging back to its pre-shock equilibrium by the sixth quarter. This pattern indicates the transient nature of demand shocks on interest rate dynamics, as market forces gradually absorb the excess demand.

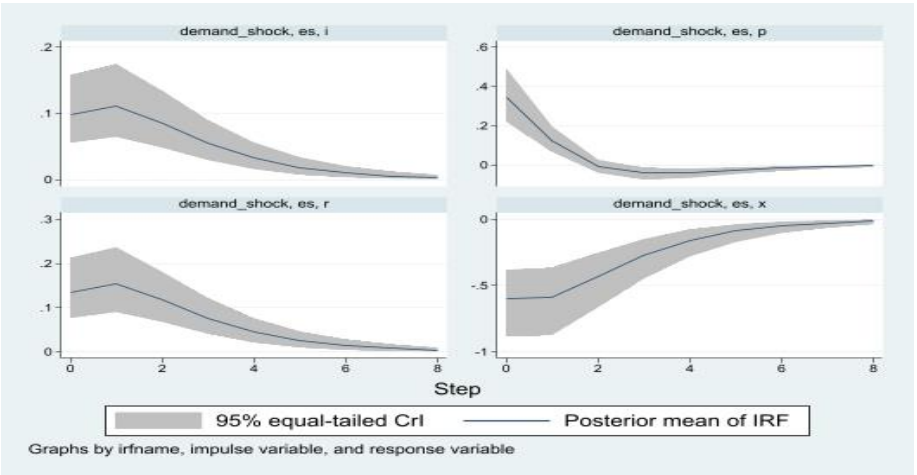
Inflationary pressures intensify sharply following the demand shock, underscoring the sensitivity of the aggregate price level to demand-side fluctuations. However, the return of inflation to its pre-shock level by the second quarter reveals the temporary nature of these price changes. This rapid adjustment is indicative of the self-correcting mechanisms within the economy, likely facilitated by monetary policy interventions.

The response of the monetary policy rate further highlights the central bank's role in mitigating inflationary pressures. The immediate and sustained rise in the policy rate until the end of the first quarter reflects the monetary authority's proactive stance in countering inflation. By the sixth quarter, as inflation stabilises, the monetary policy rate reverts to its initial level, aligning with the normalisation of macroeconomic conditions.

The output dynamics, however, reveal the recessionary consequences of demand shocks. The sharp initial decline in output highlights the contractionary effects of tightened monetary conditions and reduced economic activity. The economy's prolonged recessionary state, persisting until the sixth quarter, underscores the depth of the shock's impact. The eventual recovery to pre-shock output levels by the seventh quarter reaffirms the economy’s resilience, though the lagged adjustment underscores the significant costs of demand volatility.

In summary, Figure 3 elucidates the transient yet profound impacts of demand shocks on Sierra Leone’s economy. While inflation and interest rates exhibit a relatively swift return to equilibrium, the prolonged recessionary state of output highlights the asymmetric effects of such shocks. These findings emphasise the critical role of policymakers in closely monitoring and managing demand fluctuations to stabilise economic conditions and minimise adverse impacts on growth.

Figure 3: Response to Demand Shock



- **Productivity Shock**

The analysis in Figure 4 provides an interpretation of the macroeconomic responses to a positive productivity shock in Sierra Leone. The results highlight the sequence of variable adjustments, capturing both immediate and lagged effects, alongside the transitory and permanent impacts on the economy.

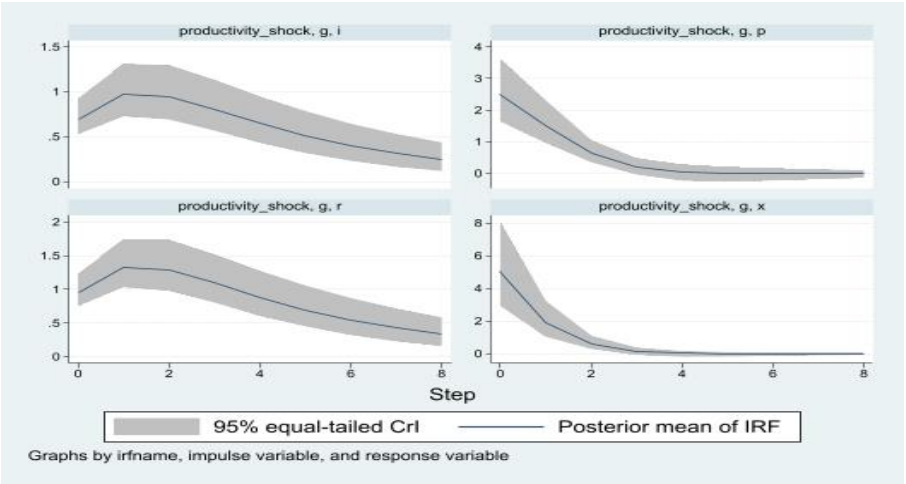
In the immediate aftermath of the productivity shock, the market lending rate increases sharply. This response reflects heightened demand for credit as firms and individuals seek to take advantage of the improved productivity environment. The rise in lending rates demonstrates the financial system's sensitivity to changes in economic productivity and its role in facilitating economic adjustments. Alongside this, inflation also increases abruptly. This initial inflationary response, driven by demand-side pressures, arises from increased consumer and investment spending spurred by higher incomes and economic optimism.

As the productivity shock progresses, other macroeconomic variables begin to adjust. The monetary policy rate increases sharply, reflecting the central bank's proactive approach to controlling inflationary pressures and ensuring economic stability. The

monetary policy rate remains elevated for several quarters, underscoring the structural implications that policymakers associate with productivity shocks. Meanwhile, output experiences a sharp rise following the shock, as the economy capitalises on enhanced productivity to increase production levels. This output gain persists until the third quarter, after which it gradually declines, returning to its pre-shock level by the fourth quarter. This reversion suggests that while productivity shocks generate short-term growth, their impact on output is cyclical rather than permanent.

Over time, inflation begins to decline, returning to its pre-shock level by the fourth quarter. This trajectory indicates that the supply-side benefits of productivity gains eventually outweigh the initial demand-side pressures, stabilising prices in the economy. The market lending rate, while gradually decreasing after its initial surge, remains above its pre-shock level, reflecting a permanent adjustment in credit market dynamics. Similarly, the monetary policy rate stabilises at a higher level than before the shock, indicating a structural recalibration by monetary authorities in response to the perceived long-term effects of improved productivity.

Panel 4: Response to Productivity Shock



- **Financial Shock**

The impulse response analysis in Figure 5 provides a coherent view of the macroeconomic effects of a financial shock in Sierra Leone, interpreted through the chain rule to highlight immediate, intermediate, and long-term effects on key variables. The responses reveal the distinct characteristics of the Sierra Leonean economy, shaped by its unique financial structure and reliance on non-monetary factors.

In response to the financial shock, interest rates exhibit an immediate and sharp increase. This abrupt adjustment reflects heightened risk perceptions or financial stress within the economy. However, the elevated interest rates gradually decline over the course of eight quarters, eventually reverting to their pre-shock levels. This pattern indicates that the impact of the financial shock on interest rates is transitory, with the financial system demonstrating a degree of resilience and capacity for adjustment over time.

Despite the significant fluctuations in interest rates, the financial shock appears to have little to no discernible impact on inflation, monetary policy, or output. The lack of responsiveness in inflation can be attributed to the dominance of non-monetary factors driving price levels in Sierra Leone. Inflation is less sensitive to variations in consumption or borrowing, and therefore, the increase in market interest rates does not significantly deter demand or influence pricing pressures. This highlights the structural nature of inflation in Sierra Leone, which is shaped more by external factors, such as import prices or supply constraints, than by domestic financial conditions.

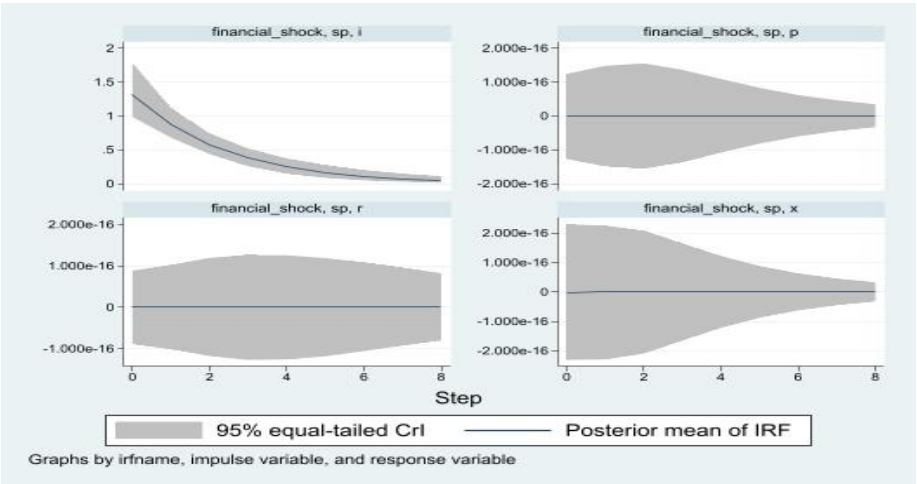
The monetary policy rate also remains unresponsive to the financial shock. This may be due to the central bank’s recognition of its limited ability to address the structural financial frictions in the economy. Factors such as the significant gap between savings and investment rates, high operating costs for commercial banks, and the prevalence of non-performing loans impose constraints that monetary policy cannot directly mitigate. Consequently, the central bank's policy adjustments remain unaffected by the financial shock, reflecting its understanding of the broader financial environment and its constraints.

Output similarly shows no significant response to the financial shock, which can be explained by the small size of the formal financial sector relative to the large informal economy. In Sierra Leone, much of the economic activity and entrepreneurial investment occurs outside the traditional banking system, rendering the transmission of financial shocks through formal savings and lending channels less effective. High lending rates and limited accessibility to formal financial services mean that entrepreneurs rely on alternative mechanisms for financing their investments. As a result, financial frictions in the formal sector have a negligible impact on overall economic output, and growth remains largely insulated from the conditions of the formal financial system.

The resilience of the financial sector to the shock is further supported by the structure of commercial banks in Sierra Leone. A substantial portion of bank profits is derived from investments in safe government securities and foreign currency trading, both of which offer relatively stable returns. This reduces the banking sector's vulnerability to financial shocks, as it is less reliant on traditional lending activities that are more susceptible to financial frictions. The ability of banks to maintain stability in their core revenue streams likely contributes to the limited macroeconomic impact observed in the impulse response.

In summary, the response to the financial shock in Figure 5 underscores the unique economic and financial dynamics of Sierra Leone. While interest rates react sharply and then normalise over time, inflation, monetary policy, and output remain largely unaffected due to the dominance of non-monetary factors, the structural nature of financial frictions, and the outsized role of the informal economy. These findings highlight the importance of understanding the distinct characteristics of the financial system when designing policies aimed at managing financial shocks and promoting sustainable growth.

Panel 5: Response to Financial Shock



5.0 Conclusion

5.1 Summary

This study estimates a small-open economy DSGE model for Sierra Leone, incorporating financial frictions to explore the dynamics of monetary policy transmission. Using Bayesian estimation, the model captures the nuanced interactions among households, firms, the monetary authority, and the financial sector, while considering the role of external shocks via the trade-weighted exchange rate. Impulse response analysis demonstrates the effects of economic, demand, productivity, and financial shocks on key macroeconomic variables.

The empirical findings underscore that monetary policy shocks in Sierra Leone are transitory and primarily influence the economy through short-term adjustments in aggregate demand. Inflation responds more significantly to exchange rate depreciation than to domestic monetary policy actions, highlighting the vulnerability of Sierra Leone's economy to external shocks. Financial frictions, while present, have limited effects on output, inflation, and monetary policy rates, reflecting structural

characteristics such as the dominance of the informal sector and inefficiencies in the formal financial system.

5.2 Policy Recommendations

The following policy recommendations align with the findings and aim to address challenges:

- **Enhancing Monetary Policy Effectiveness**: The Bank of Sierra Leone (BSL) should adopt a more proactive and adaptive monetary policy framework to mitigate the short-term effects of demand and productivity shocks. Rapid adjustments to the monetary policy rate can help stabilise inflation and foster long-term economic resilience.

- **Promoting Financial Inclusion**: To alleviate transmission bottlenecks in monetary policy, BSL should prioritise financial inclusion policies that integrate the informal sector into the formal financial system. Incentives such as reduced transaction costs and targeted credit programs can encourage participation.

- **Diversifying the Economy**: Policymakers should focus on export-led growth strategies to mitigate the adverse effects of exchange rate volatility. Boosting production in sectors such as mining, agriculture, and fisheries can enhance foreign exchange availability and reduce reliance on imports.

- **Strengthening Financial Sector Stability**: Regulatory measures should address inefficiencies in the banking sector, such as high non-performing loans and operational costs. Improved corporate governance and risk management frameworks can help stabilise credit markets and enhance the sector's contribution to economic growth.

- **Building Resilience to External Shocks**: Given the limited impact of monetary policy on structural inflation drivers, efforts should focus on managing supply-side constraints and diversifying trading partners to reduce exposure to global commodity price fluctuations.

- **Refining Data and Analytical Models**: To overcome limitations related to data availability and model assumptions, future research should incorporate broader datasets and alternative modelling approaches. Expanding the time-frame beyond 2011–2020 and considering behavioural economics frameworks may yield deeper insights.

Limitations: While the DSGE model effectively captures key dynamics, its assumptions of rational expectations and perfect foresight may not fully align with the behavioural realities of economic agents. Additionally, the model's inability to account for all external economic shocks underscores the need for complementary analytical tools.

This study contributes to the broader understanding of financial frictions and monetary policy in small-open economies, offering actionable insights for policymakers in Sierra Leone. By addressing identified challenges and leveraging the findings, the BSL can foster price stability, economic resilience, and sustainable growth.

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APPENDICES

Appendix 1: Model Estimation without Block Parameters

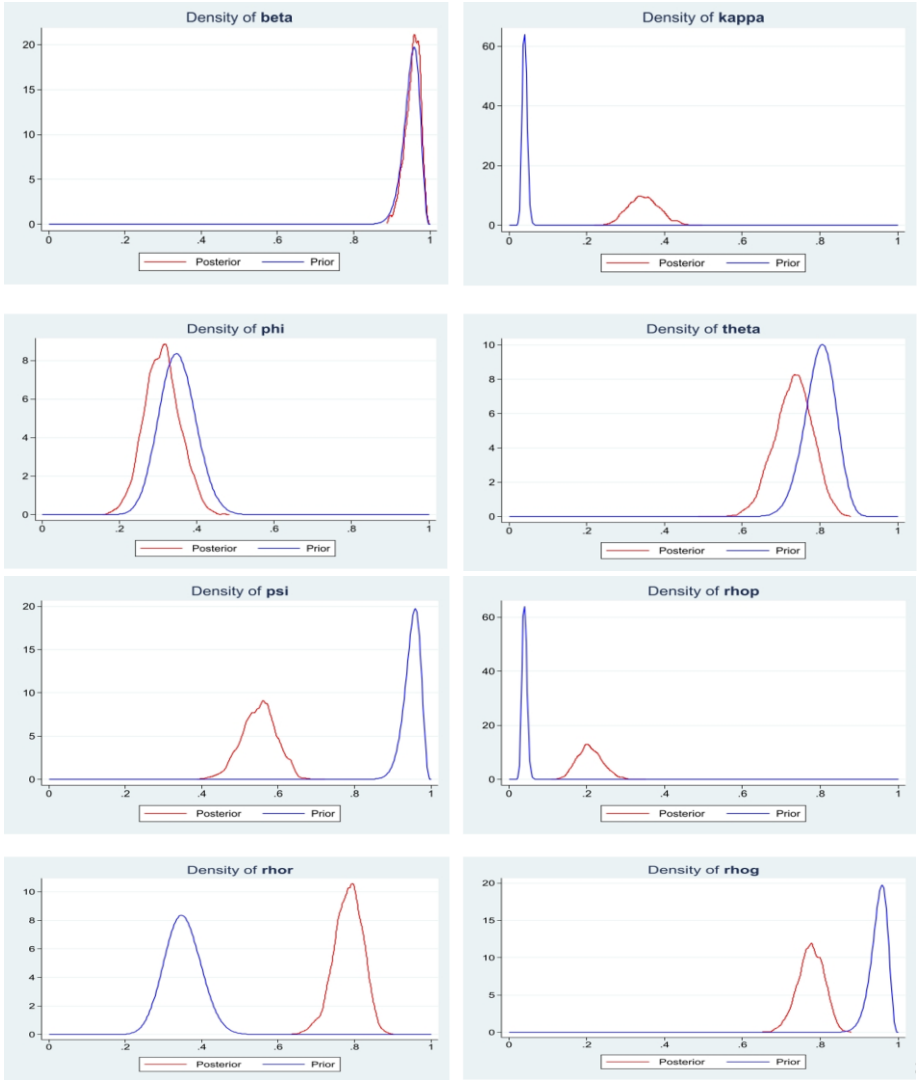
Bayesian linear DSGE Model				**MCMC iterations**		12,500
				Burn-in		2,500
Random-walk Metropolis-Hastings Sampling				**MCMC sample size**		10,000
				Number of obs.		39
				Acceptance rate		0.141
Sample: 2011Q2 thru 2020Q4				**Efficiency**	**Min.**	0.001568
					Avg.	0.005894
Log marginal-likelihood = 384.59501					**Max.**	0.01304
	Mean	**Std. dev.**	**MCSE**	**Median**	**Equal-tailed**	
					95% cred.	**interval**
rhor	*.7947464*	*.0200832*	*.003519*	*.7960984*	*.7543221*	*.8322394*
psi	*.5686506*	*.0416597*	*.004869*	*.570128*	*.4837977*	*.647478*
Theta	*.6882421*	*.0474875*	*.005188*	*.6905968*	*.5890496*	*.7747464*
rhop	*.1771505*	*.0254463*	*.002575*	*.1769028*	*.1293332*	*.2298978*
Beta	*.9562655*	*.0203372*	*.001918*	*.9606688*	*.9101529*	*.9854781*
Kappa	*.3767965*	*.0290637*	*.004949*	*.3751629*	*.3223556*	*.433979*
Phi	*.2990247*	*.0419396*	*.006146*	*.3005387*	*.2099846*	*.375779*
Rhou	*.5573313*	*.0252256*	*.002209*	*.5598384*	*.5018589*	*.6012031*
Rhog	*.8803861*	*.0160131*	*.002641*	*.8798988*	*.8480121*	*.9103098*
Rhoes	*.5669138*	*.0372186*	*.004005*	*.5685116*	*.4880662*	*.6319581*
Rhosp	*.6948415*	*.0357171*	*.004497*	*.6956811*	*.6244062*	*.7646303*
Sd(e.u)	*2.279139*	*.1866222*	*.037774*	*2.295076*	*1.861314*	*2.619298*
Sd(e.g)	*1.151385*	*.0559486*	*.013081*	*1.14724*	*1.059369*	*1.262657*
Sd(e.es)	*1.544591*	*.082105*	*.015373*	*1.548152*	*1.37929*	*1.702182*
Sd(e.sp)	*1.099549*	*.103329*	*.026092*	*1.099264*	*.916858*	*1.299287*

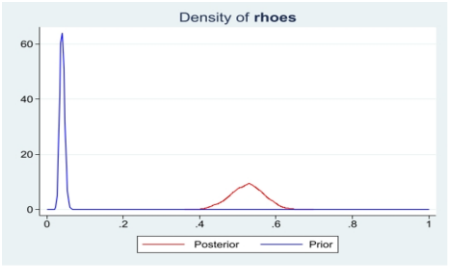
Note: There is high autocorrelation after 500 lags.

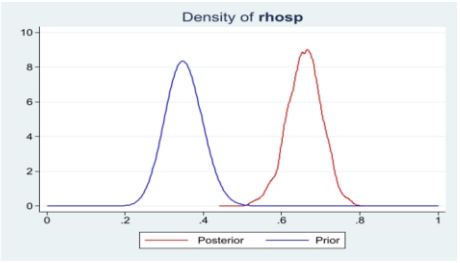
Appendix 2: Efficiency Summary Statistics without block parameters

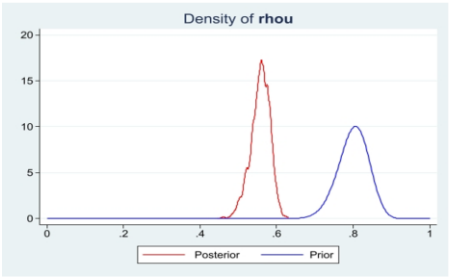
Efficiency Summary		**MCMC Sample**		10,000
		Efficiency	**Min.**	0.001568
			Avg.	0.005894
			Max.	0.01304
	ESS	**Corr. time**		**Efficiency**
rhor	***32.58***	***306.95***		***0.0033***
psi	***73.22***	***136.58***		***0.0073***
Theta	***83.77***	***119.37***		***0.0084***
rhop	***97.68***	***102.38***		***0.0098***
Beta	***112.38***	***88.98***		***0.0112***
Kappa	***34.49***	***289.90***		***0.0034***
Phi	***46.56***	***214.76***		***0.0047***
Rhou	***130.39***	***76.69***		***0.0130***
Rhog	***36.76***	***272.07***		***0.0037***
Rhoes	***86.36***	***115.80***		***0.0086***
Rhosp	***63.07***	***158.54***		***0.0063***
Sd(e.u)	***24.41***	***409.69***		***0.0024***
Sd(e.g)	***18.29***	***546.65***		***0.0018***
Sd(e.es)	***28.52***	***350.59***		***0.0029***
Sd(e.sp)	***15.68***	***637.61***		***0.0016***

Appendix 3: Prior-posterior plot for the estimated model without blocked parameters



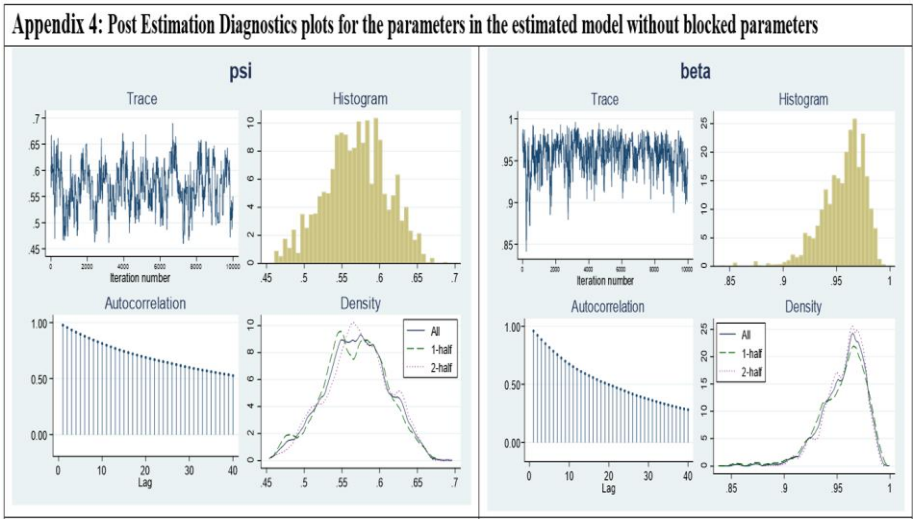


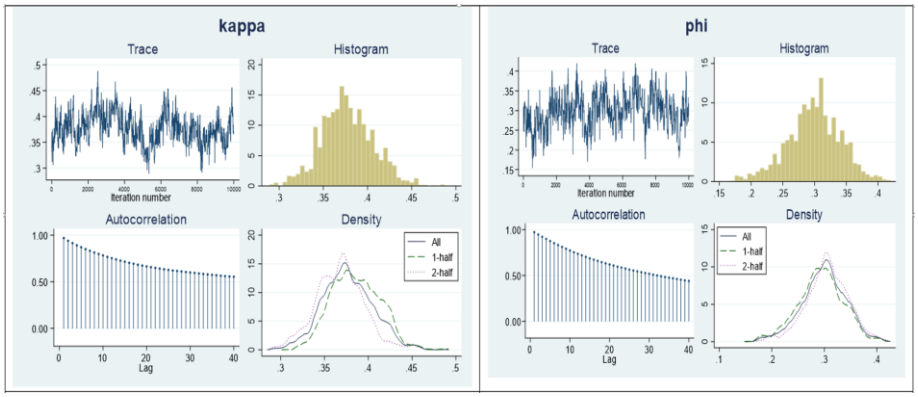




Source: Authors Computation Using STATA 17

Appendix 4: Post Estimation Diagnostics plots for the parameters in the estimated model without blocked parameters

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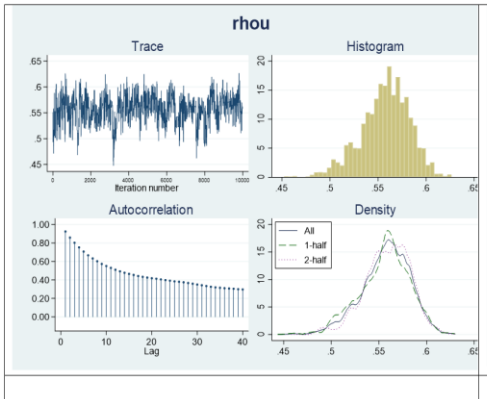
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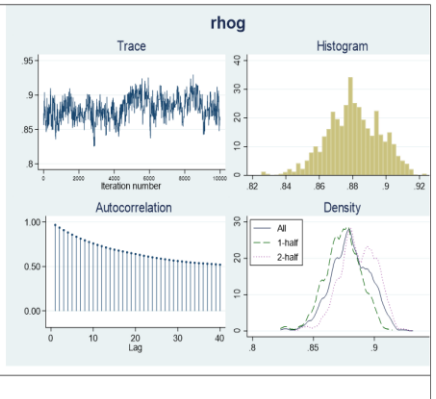
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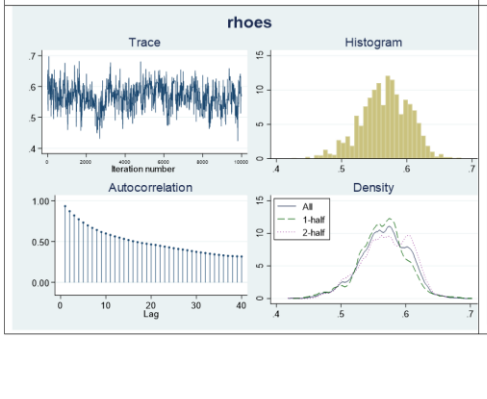
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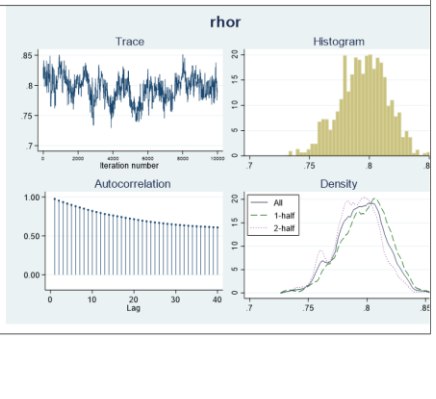
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CHALLENGES TO GHANA'S EXPORT DIVERSIFICATION DRIVE: A COMPARATIVE ANALYSIS OF SELECTED COUNTRIES, USING THE ECONOMIC COMPLEXITY AND PRODUCT SPACE FRAMEWORKS

Emmanuel Owusu-Afriyie[1]

ABSTRACT

This study examines a major challenge undermining Ghana's export diversification drive. The study is anchored on the theoretical arguments that posit that the nature of products constituting a country's export basket and reflecting its productive capabilities acquired over the years matters a lot in any diversification drive. By employing the concepts of Economic Complexity Index (ECI) and Product Complexity Index (PCI), the study undertakes a comparative analysis between Ghana and selected countries (Nigeria, Singapore, and Malaysia) to establish why Ghana's export basket is less diversified. The study generates Product Space and Revealed Comparative Advantage (RCA) based on trade data at the HS 4-digit classification level for 1240 products for the period 1995 to 2016. It proceeds to use the ECI, PCI, and RCA to examine sectors that have emerged based on the products for which Ghana has gained comparative advantage, and how that has contributed to its diversification drive. The study provides evidence to show that Ghana and other similar countries in the Sub-Sahara African region are caught in the trap of producing and exporting products that are of low sophistication level (low PCIs), reflecting in low and negative ECIs of their export baskets. This suggests that the embedded productive capabilities or the collective know-how in these products are limited. Thus, the opportunities for Ghana to leverage the productive capabilities acquired over the years to chart new paths for structural transformation and subsequent diversification of the economy are constrained. Apart from encouraging Ghana to follow the experiences of Singapore and Malaysia that focused on products with high PCIs to underpin their structural transformation and export diversification drive, Ghana may explore the opportunities

[1] The Author is a staff of Bank of Ghana in the Financial Stability Department. However, the views expressed in this article are his personal views and not that of the Bank of Ghana.

from the 91 identified frontier products, where it has revealed comparative advantage with high PCIs to support its diversification drive coupled with appropriate industrial and fiscal policy support.

Keywords: Economic Complexity, Product Space, Export Diversification, Ghana
JEL Classification: F14, O31, F41, O57

1. 0 Introduction and Related Literature

This study seeks to investigate whether the nature of products Ghana produces and exports has helped in its structural transformation agenda towards a more diversified export base. To undertake this investigation, the study employs the concepts of Economic Complexity and Product Space developed by Hausmann et al (2013).[2] The Economic Complexity Index (ECI) construct is used to assess the pace of accumulation and evolution of productive knowledge (capabilities) embedded in Ghana's major products, reflecting the country's productive structure. Subsequently, within the Product Space construct, the study identifies the products that offer opportunities for Ghana, based on its acquired productive know-how, to explore extensively the value addition spectrum that would enhance its export diversification drive and economic development.

The importance of export growth as a key ingredient in economic growth has been established by many studies both theoretical and empirical (Oyolola, 2007; Darku,

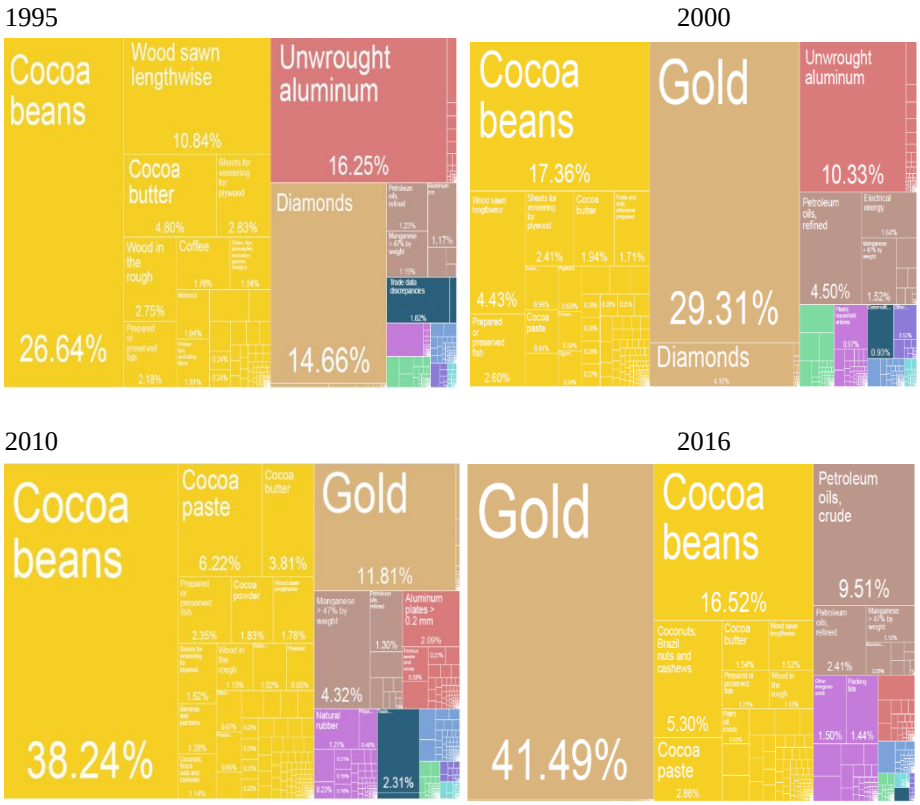
[2] According to Hartmann et al (2017, p. 7)
"The Economic Complexity Index (ECI) measures the sophistication of a country's productive structure by combining information on the diversity of a country (the number of products it exports), and the ubiquity of its products (the number of countries that export that product) (Hidalgo & Hausmann, 2009). The intuition behind ECI is that sophisticated economies are diverse and export products that, on average, have low ubiquity, because only a few diverse countries can make these sophisticated products. By the same token, less sophisticated economies are expected to produce a few ubiquitous products. ECI exploits this variation in the diversity of countries and the ubiquity of products to create a measure of a country's productive structure that incorporates information about the sophistication of products".
Product Space, on the other hand, is a network of relatedness between products that demonstrate that upscale products are located in a densely connected core whilst products of low-income elasticity occupy in a less connected periphery, (Hidalgo et al. 2007).

2012; Thirlwall and Hussain, 1982). However, these studies fail to distinguish between the relative contributions of the volumes of a country's exports against the composition of its exports to its growth agenda. More especially in the classical international trade theories by the Ricardian and Heckscher-Ohlin (H/O) models, countries improve the welfare of their citizens by specializing in the production and export of products that they, either have a comparative advantage or cost advantages, because their endowed resources are either intensively or abundantly used (Ricardo,1817). In the process, structural transformation of the economy is perceived as a passive outcome of the process of gaining comparative advantage, (Hausmann and Klinger, 2008).

In recent times the discussions on export growth have evolved, shifting focus from the volumes exported to more importantly the composition of the products constituting a country's export basket. This gives credence to the notion that the nature of products that a country exports matters; with significant implications for its structural transformation that impacts both its current level of economic growth and prospects for future economic progress. According to Hausmann et al. (2007), the embedded productivity content in the export basket of a country is very crucial for determining which country would enjoy accelerated economic growth and the one that would slack. The basis of this logic is that the degree of sophistication of products tends to be disproportional and in the long run countries whose composition of production and export reflects high levels of variety and sophistication are more likely to experience higher levels of income[3].

[3] Sophistication is said to capture more than technical characteristics to encompass product differentiation, product fragmentation, resources availability and other factors, (Lall et al. 2005).

Figure 1: The Composition of Ghana's Export Basket for Selected Years



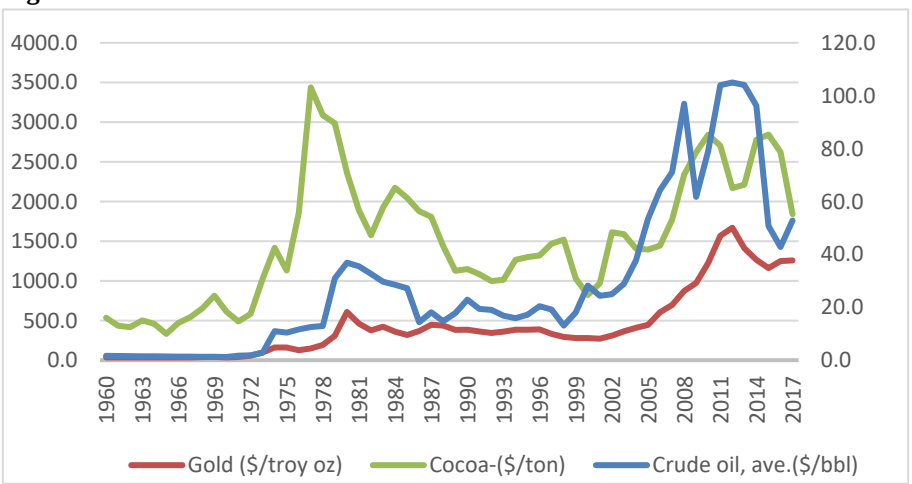
Source: Atlas of Economic Complexity, 2018 and Author

Consistent with the reasoning above, it has become imperative to consider the composition of the export basket of developing countries like Ghana. This is because the nature of products constituting its export basket has implications for any structural transformation agenda aimed at diversifying into new products with higher value addition and laying the basis for increased manufacturing activity with prospects for

sustainable growth and job creation. This has instigated renewed research interest in this subject matter.

Figure 1 presents the composition of Ghana's export basket for selected years to highlight the issue of persistence in the level of concentration of its export basket. This lends credence to the fact that Ghana's export composition over the years has been dominated by a few primary products (cocoa beans, gold, and crude oil). This situation portends limited diversification into other products that may set the country on the path of exploring gains to be secured on the value-chain spectrum.

Figure 2: Prices of Selected Commodities: 1960-2017



Source: World Bank Commodity Price Data, 2019 (The Pink Sheet)

Figure 2 presents developments in the international prices of selected primary commodities measured in US dollars. Cocoa prices are measured on the right axis, whilst both gold and crude oil prices are measured on the left axis. Trends in the selected global commodity prices suggest increased volatility over the period 1960 to 2017 with adverse implications for macroeconomic targets of the countries producing and exporting these primary products. These trends are consistent with Aditya and

Acharyya (2012), who argue that countries that continuously concentrate on the export of primary products experience terms of trade shocks, slack in productivity growth, and limited value addition. This position reinforces the Prebisch-Singer hypothesis that countries that specialise in primary commodities, coupled with slack in the pace of technical progress in the primary sector, suffer from adverse trends in the commodity terms of trade and cause them to lag behind countries that manufacture products in terms of development, (Prebisch, 1950; Singer, 1950). The studies of UNCTAD (2012) and Cavalcanti, Mohaddes, and Raissi (2012) argue that commodity-exporting countries are confronted with the potential risk of excessive price developments, which has negative consequences for their economic growth.

Hence, the diversification of the export basket of countries such as Ghana that predominantly undertake activities in the primary sector becomes pertinent. This is because apart from helping to minimise the adverse effects of price volatilities, export diversification has the potential to create networks of activities that facilitate sustained and inclusive growth. This focus on diversification drive equally ties into the recent shift in public policy from an industry-neutral to an industry-specific approach encouraging governments to provide backstops for activities within the value-chain spectrum (Chandra and Rodarte, 2009).

The critical questions are that: (i) If export diversification is key, and the nature of products constituting a country's export basket matter in this effort, then why is Ghana's export basket less diversified? (ii) And what products should Ghana be focusing on in its export diversification drive? (iii) Does Ghana possess the capabilities to produce and export such products? (iv) How do we identify such products for export diversification drive and industrialisation policy?

To address these issues this study employs a framework that combines the concepts of Economic Complexity and Product Space introduced by Hausmann et al. (2013), Hausmann et al. (2007) and Hidalgo (2009).

According to Hausmann et al. (2013), the knowledge base of a society is conditioned by the diversity of knowledge across individuals and how through a complex web of

interactions individuals can deploy these diverse abilities to effective use. They argue further that knowledge embedded in the society can be categorised into explicit knowledge and tacit knowledge. Explicit knowledge is easy to acquire and can be common in many countries. Therefore, if all knowledge is classified as explicit, then the pace of convergence among countries is likely to be faster. It is worth noting that one of the core issues of development economics is to identify the source of disparity in prosperity amongst countries. The amount of tacit knowledge each country possesses, which is difficult to be embedded, can be traced as key in explaining disparities in incomes amongst countries. The point must be made that, technological knowledge which is an important component of the endogenous growth model, consists of three main components, which are the tools, the blueprint or codes, and the know-how. Countries with substantial resources can easily procure the tools and blueprints associated with technology. However, the same cannot be said of know-how. The know-how component, akin to mental wiring, demonstrates the ability of the brain to perform a task through the process of imitation and repetition as well as the process of diffusing the knowledge generated and preserved for use. This is considered more important to propel growth (Hausmann et al. 2013). Specialisation is a key component of the process of embedding this know-how, which is both time and resource intensive. Besides, the individual who acquires such productive knowledge is likely to function efficiently in a society where the know-how is internally coherent with the collective know-how of the society. Indeed, the concentration of this specialised productive knowledge at the level of the individual, organisations, or network of organisations has been referred to as capabilities. Invariably, products are produced through the combination of specific non-tradable productive inputs considered as capabilities (Hausmann and Hidalgo, 2010).

Hidalgo and Hausmann (2009) argue that the development of countries is based on the number of capabilities they can accumulate and utilise in the production of goods and services. Countries that have these capabilities in considerable measure can make many things and tend to be more diversified. On the contrary, products that required more capabilities are going to be harder to make, therefore fewer countries are going to be able to make those products. As a result, poorly diversified countries are likely to make products that are on average made by many other countries, while highly

diversified countries produce products that are on average produced by few other countries, (Hausmann and Hidalgo, 2010). Countries endowed with many capabilities to produce more diverse goods and at the same time produce goods requiring a lot of capabilities such that only a few countries can produce are classified as complex or sophisticated.

Economic Complexity, therefore, reflects how both the intricate network of interactions of activities coupled with the receptacle of productive knowledge generated within the society are channelled into the production of sophisticated goods for export. More importantly, increased levels of economic complexity positively affect a country's level of per capita income and set it on a course for future growth, (Hidalgo et al, 2007). In this regard, relatively richer countries tend to produce and export more sophisticated goods, whilst relatively poor countries on average tend to produce and export less sophisticated goods. Through a cross country growth model controlled for measures of governance, human capital, competitiveness, and financial depth, Hausmann et al., 2013 establish that the measure of economic complexity is superior to other covariates in explaining growth.

As a country evolves on improving the economic complexity of its export basket in the presence of existing density of complementary capabilities, the process of export diversification will be feasible and enhanced. This suggests that the marginal returns for additional capability tend to increase once there are existing complementary capabilities. This brings to the fore the concept of Product Space. The Product Space framework establishes a country's current collective know-how within the global technology frontier and the proximate complex goods within its technology frontier that the acquired capabilities can be deployed easily to produce (Abdon and Felipe, 2011). To this end, both the economic complexity and product space constructs are key in exploring the structural transformation possibilities of a country that would underpin its export diversification drive.

The rest of the paper is organized as follows: Sections 2 and 3 outline the empirical strategy and the sources of the data used for the investigation. Section 4 focuses on the findings, while Section 5 ends with a conclusion.

2.0 Methodology

2.1 Measuring Economic Complexity

In general, measuring economic complexity of any country requires that we generate two indicators. First, a measure of the level of export diversification of a country reflecting in the number of products it produces (in which case the more products the country produces the better), and secondly a measure of the ubiquity of products which demonstrates the number of countries producing those products (in which case less ubiquitous products are considered more complex since fewer countries produce them due to the complex network of relationships required for their production). Thus, according to Hausmann et al. (2013) diversity and ubiquity can be expressed as:

$$Diversity = k_{c,o} = \sum_{p} M_{cp} \quad 1$$

$$Ubiquity = k_{p,o} = \sum_{c} M_{cp} \quad 2$$

where M_{cp} is a matrix that is 1, if a country c produces product p and 0 otherwise. Both the diversity and the ubiquity can be measured by summing over the rows or columns of that matrix.

To generate the Economic Complexity Index to gauge the amount of productive knowledge (capabilities) a country has accumulated or required to produce a particular product, higher difference levels of both indicators must be considered by using the average of each other in an iterative process to correct for their initial levels. The reason is that the fact that two countries are equally diversified in terms of the number of products they produce does not mean that they are equally sophisticated[4]. There is the need to check on average the number of countries that can produce the diverse products. In other words, the average ubiquity of the products. Therefore, for a country, we must calculate the average ubiquity of the products exported, the average

[4] For instance, if a natural resource endowed country has crude oil, which tends to be less ubiquitous because few countries may be so endowed, this does not necessarily make it more sophisticated because the capabilities in extracting crude cannot be easily deployed to other products. But if a country gains capability in the production of a product like X-ray machines, which tends to be produced by a few countries with complex interactions, then this will enhance the sophistication of the country and the level of capabilities as well as its deployment to producing other products will equally be enhanced.

diversity of the countries that can produce those products and repeat the process at higher difference levels in an iterative manner in search of some convergence. Equally, for a product, we must calculate the average diversity of the countries that can produce them and the average ubiquity of the other products that those countries produce. Recursively, this can be expressed as

$$k_{c,N} = \frac{1}{k_{c,o}} \sum_{p} M_{cp} . k_{p,N-1} \quad 3$$

$$k_{p,N} = \frac{1}{k_{p,o}} \sum_{c} M_{cp} . k_{c,N-1} \quad 4$$

Equation 4 is substituted into equation 3 to obtain

$$k_{c,N} = \frac{1}{k_{c,o}} \sum_{p} M_{cp} \frac{1}{k_{p,o}} \sum_{c'} M_{c'p} . k_{c',N-2} \quad 5$$

$$k_{c,N} = \sum_{c'} k_{c',N-2} \sum \frac{M_{cp} M_{c'p}}{k_{c,o} k_{p,o}} \quad 6$$

which can also be written as

$$k_{c,N} = \sum_{c'} \tilde{M}_{cc'} k_{c',N-2} \quad 7$$

where $\tilde{M}_{cc'} = \sum_{p} \frac{M_{cp} M_{c'p}}{k_{c,o} k_{p,o}}$

The equation 7 is satisfied when $k_{c,N} = k_{c,N-2} = 1$ and this is the eigenvector of $\tilde{M}_{cc'}$ linked to the largest eigenvalue. Since the eigenvector is a vector of ones, the information content is limited. Hence, the eigenvector linked to the second largest eigenvalue that captures the largest amount of variance in the system is used as the measure of economic complexity index (ECI)

$$ECI = \frac{\vec{K} - < \vec{K} >}{stdev\left(\vec{K}\right)} \quad 8$$

where $\vec{K}$ = the eigenvector of $\tilde{M}_{cc'}$ linked to the second largest eigenvalue and < > is average

An analogous definition for the Product Complexity Index can be derived[5]. Since the problem is considered as symmetric, one can just transpose the index of countries (C) with that for products (p) consistent with equation 8 above.

$$PCI = \frac{\vec{Q} - < \vec{Q} >}{stdev\left(\vec{Q}\right)} \qquad 9$$

Where $\vec{Q}$ = the eigenvector of $\tilde{M}_{pp'}$ linked with the second largest eigenvalue.

2.2 Revealed Comparative Advantage

To construct both the ECI and the product space, one must construct another index referred to as Revealed Comparative Advantage (RCA) by Balassa (1965). The RCA will ensure that countries and products are comparable by considering the relative size of the export volumes of countries and that of the world trade of the products. Balassa, *op. cit.*, argued that a country has a revealed comparative advantage in a product if it exports more than its "fair" share. In order words the systemic importance of that product in the total global export of that product.

In this case, if X_{cp} is to represent the export of a country C in the product p, then the revealed comparative advantage that the country C has in product p can be expressed as:

$$RCA_{cp} = \frac{\frac{X_{cp}}{\sum_c X_{cp}}}{\frac{\sum_p X_{cp}}{\sum_{c,p} X_{cp}}} \qquad 10$$

[5] Product Complexity exhibits the level of sophistication of a product and for that makes its strategic value. Economic complexity on the other hand shows the level of sophistication of a country's export basket.

where the numerator represents the share of the product in a country's export basket and the denominator represents the share of the product in total world trade.

This index is used to construct a matrix that links each country to the products it produces. Here, the entries in the matrix are 1 if country c exports product p with RCA greater than 1, and 0 otherwise.

We can therefore have:

$$M_{cp} = \begin{cases} 1 \text{ if } RCA_{cp} \geq 1 \\ 0 \text{ otherwise} \end{cases}$$

To incorporate the effect of price fluctuations of the commodities involved, a modified definition of RCA where the denominator represented the average over the previous three years is used for generating the indices.

2.3 Product Space

The product space framework suggested and developed by Hidalgo et al. (2007), Hausmann and Klinger (2007) and Hausmann et al., (2013) can be used to identify sectors and products with potentials for improved competitiveness based on a country's current set of productive capabilities. The theoretical framework underpinning the product space concept is developed on a model that suggests that human capital tends to be product-specific and the degree of substitutability across products quite heterogeneous, (Hidalgo et al, 2007). A similar theoretical argument has been advanced by Lazear (2009) that firm-specific human capital can be considered as a weighted combination of skills unique to the firm. However, the same weighted combination of skill may not be a perfect substitute required for another firm. The same theory equally rhythms well with the models of learning-by-doing.

In constructing the product space, the key consideration is to focus on products outside the current export basket of the country, yet within adjacent possibilities and offer opportunities for improving the average level of sophistication of the products in the export basket of a country (Hausmann and Jasmina, 2015). Since, by and large, a

country's economic advancement is likely to be associated with an increased level of products sophistication and economic complexity as well as consistent with the claim that economic development tends to be path-dependent, countries are better placed to deploy embedded capabilities to new products within their adjacent possibilities. Thus, to enhance the export diversification agenda of Ghana, the product space concept is used to discover new products within its feasible range given its current capabilities. At the same time, it is used to identify products that offer prospects for improving the collective level of sophistication of Ghana's export basket and their strategic value for structural transformation leading to a more diversified export base.

The following sub-sections are devoted to explaining some of the key indices used to operationalize the product space construct.

2.4 A Measure of Proximity

To produce a product, one will require some capabilities. The capabilities of a country can be captured by the proximity between the products being currently produced and the desirable products outside its current export basket. Acquired capabilities used in the production of some current products can either be deployed to produce other goods or maybe unique to those products. Since capabilities cannot be observed, the measure of proximity is used to gauge the similarity between the capabilities required to produce a pair of goods by assuming that they are co-exported. Hence, we assume that to the extent that two products share most of the requisite capabilities, then the country that exports one of the products is more likely to export the other, otherwise they are not likely to be co-exported.

To this end, we base the proximity measure on the conditional probability that if a country exports a product y then it is likely to export y'. The conditional probability is not considered to be symmetric, so we selected the minimum of the probability of exporting product y', given y and the reverse is true.

We define the proximity measure as:

$$\phi_{yy'} = \frac{\sum_c M_{cy} M_{cy'}}{Max\left(k_{y,o}, k_{y',o}\right)} \qquad 11$$

Where $M_{cy} = 1$ if a country c exports product y with $RCA > 1$ and 0 otherwise, $k_{y,o}$ is the ubiquity of product y .

2.5 Positioning Countries within the Product Space

To offer further clarity on the product space construct, Hausmann et al. (2013) use a metaphor to describe the network structure. In this case, countries are considered as 'Monkeys' and products as 'Trees'. One can readily surmise that 'monkeys' in dense forest with trees closed to each other can effortlessly move across the 'trees' (products). It will, however, require a lot of effort and agility on the part of 'monkeys' that are in the sparse forest to easily move about. In like manner, countries producing products that are in the dense part of the product space and surrounded by a lot of products will find diversification easier than countries producing products located in the peripheral. In what follows, we describe the matrices which established such product networking and the positioning of countries.

2.5.1 A measure of Distance

A country can infer the deficit in capabilities to reach out to new products by using the concept of distance. It is used to calculate the sum of the proximities between a product and all the products that a country may not be currently exporting. This is normalised by the sum of proximities between all products and y' (where y' is the weighted proportion of products connected to the good y that country c is not exporting). The weights are represented by the proximity index. In this case, if the country c is exporting most of the products connected to the product y , then the distance will be shorter and close to zero, otherwise, it will be close to 1. We can specify the measure for distance as:

$$d_{cy} = \frac{\sum_c \left(1 - M_{cy'}\right)\phi_{yy'}}{\sum_{y'} \phi_{yy'}} \qquad 12$$

Thus, with the distance measure, we can gauge how far each product will be from a given country's current export basket. It is worth noting that the level of economic progress of a country can be largely linked to the complexity of its products mix, thus a country stands to gain, the closest are most of the current products in its export basket to complex products within the product space. This situation will offer better opportunities for diversification.

Hence, this opportunity value, also referred to as complexity outlook can be expressed as:

$$Complexity \cdot Outlook_c = \sum_{y'} \left(1 - d_{cy'}\right)\left(1 - M_{cy'}\right) PCI_{y'} \quad 13$$

where PCI is the product complexity index of the product y' .

Higher Complexity Outlook value may suggest that a country is positioned in a location within the product space such that it is either close to more products or more complex products or both.

Another measure, the Opportunity Value is used to establish the opportunity to be gained from a given complexity outlook obtained. The opportunity gain measure is used to capture the relative contribution of an additional product with an increasingly higher level of product complexity. This can be specified as:

$$Opportunity \cdot gain_c = \left[\sum_{y'} \frac{\phi_{yy'}}{\sum_{y''} \phi_{y''y'}} \left(1 - M_{cy'}\right) PCI_{y'} \right] - \left(1 - d_{cy}\right) PCI_y \quad 14$$

2.6 Data Source

The study uses data from the Harmonised System 4-digit classification level trade statistics (HS4 data) at a more granular level (disaggregated into 1,240 different products). It is accessed from the MIT Observatory of Economic Complexity (2018) and the Harvard Atlas of Economic Complexity websites (2018). Data on World Bank classification of income levels is obtained from World Development Indicators (2018), World Bank. Data on per capita GDP is obtained from the World Economic Indicators (2018). Then the Lall classification of products are extracted from the United Nations COMTRADE database.

3.0 Findings

The analyses here follow the descriptive approaches of Hausmann and Jasmina (2015) and Fortunato et al. (2015). The various indexes reflecting Economic and Product Complexities derived by using Reveal Competitive Advantage index (ECI, and PCI, RCA), as well as the measures of distance and opportunity gains within the product space frontier are used either individually or collectively to address the key issues raised for investigation.

Specifically, the following analytical procedure is followed:

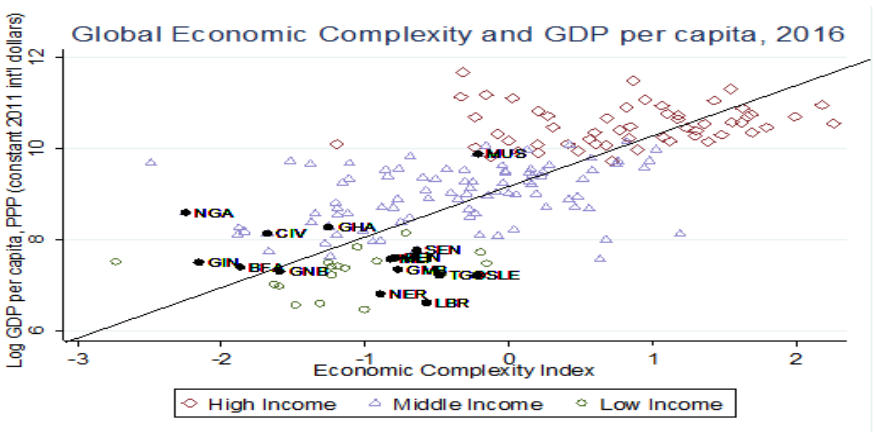
- Examine the relationship between ECIs and per capita incomes.
- Trace Ghana's accumulation of capabilities as reflected in the evolution of its ECIs and compared the same with some other countries and regions.
- Examine the products for which Ghana possesses RCA and how they compare with other countries in the ECOWAS sub-region.
- Outline how Ghana's RCAs have evolved between the years 2000 and 2016 by adopting a categorisation scheme of the RCAs used in the literature. The various categories of the RCA are then compared/crosstab with the level of product sophistication and product community categories to demonstrate how Ghana is more concentrated in less sophisticated products with constraining effects on its export diversification drive. This is done in the context of some selected country comparisons.
- In a similar vein, a comparative analysis is done for the same countries in terms of the evolution of their product space (between two periods), since that has implications for both current and future structural transformation.
- Identify new products ("frontier products") within Ghana's current productive knowledge with potential for aiding its structural transformation agenda towards a more diversified export base.
- Examine how the frontier products can be promoted within the ECOWAS regional trade, given the region's derived import intensity for each of the products.

3.1 The Relationship between ECIs and Income Per Capita

Since the ECIs reflects the amount of productive knowledge/know-how embedded in an economy, they tend to have a strong link with the levels of income for countries. Figure 3 presents the relationship between ECIs and per capita income for 220 countries with specific highlights on the 15 ECOWAS countries.

From the graph, countries are separated per the World Bank's classification of income levels. Low-income countries are denoted in circles, middle-income countries in triangles and high-income countries in squares. In a diminishing order, countries in the high-income group generally tend to have relatively higher levels of ECIs than the other income groups. Ghana and its peers in the ECOWAS region seem to have relatively lower ECIs consistent with their income groups, albeit at some degree of heterogeneity. This outcome is consistent with the study by Hausmann et al., (2013) which suggests that controlling for countries' natural resources, ECIs explain about 78 percent of the variations in income across 128 countries. Hence, more complex economics are more likely to have higher levels of income.

Figure 3: Global Economic Complexity Index and GDP Per Capita, 2016



Source: Author's calculations, 2018

3.2 Evolution of Ghana's Economic Complexity

Consistent with the explanation of ECI as a measure of the level of productivity of a country and embedded in the process of capabilities accumulation in a knowledge-intensive setting that finds expression in the nature/characteristics of countrie' export, we examine the trend of Ghana's ECI for the period 1995 to 2016 and compare that with Nigeria for the ECOWAS sub-region analysis, and Malaysia and Singapore within East Asia and Pacific sub-region. The basis for selecting Malaysia and Singapore for comparison is that they have had exceptional performance in export-led growth. In addition, Malaysia has some historical parallels with Ghana, in terms of having the same year of independence (1957) and the initial industrial policy orientation. It would be noted that in the early stages of development, both countries opted for import substitution as a key industrial policy tool to transform their economies from primary production into more industrialised economies with significant emphasis on manufacturing export. Ghana's effort did not yield much desirable outcomes. Singapore gained independence in 1965 but turned their challenging circumstances into opportunities through deliberate government policies to engage both nationals and non-nationals in their development effort[6]. Nigeria is selected because it is a peer country and to demonstrate that being a resource-rich country is just a matter of geology, but not a necessary condition for knowledge accumulation. This is because of the less ubiquitous nature of their production and export, mainly crude oil[7].

Figure 4 depicts Ghana's average ECI for the period 1995 to 2016 as -1.22 which compares favourably to the -2.21 for Nigeria, a resource-rich country, but unfavourably to the two East Asian countries, Malaysia and Singapore, which post positive average ECIs of 0.63 and 1.39, respectively, for the same period. Ghana's weak effort at accumulating capabilities as reflected in the negative average ECI could partly account for its inability to match the export performance of frontier countries

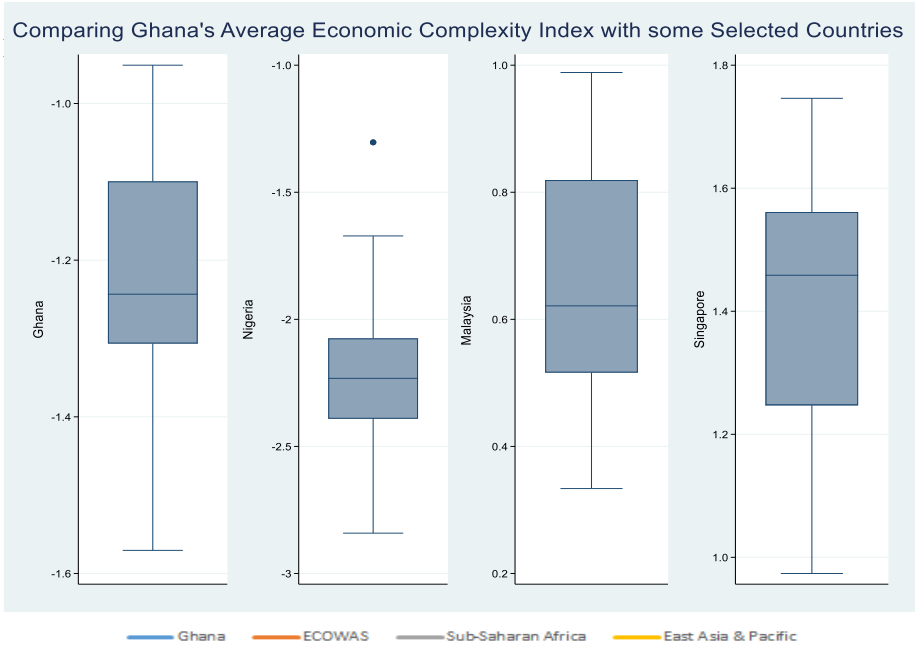
[6] Both countries from the East Asian are also shining examples of good governance.

[7] In general, less ubiquitous products are supposed to be produced by a few countries because of the complex network of processes involved and the high knowledge intensive requirement as well as the spillover effects they generate. Geology may lead to some few countries producing such natural resources.

like Malaysia and Singapore that exhibit sustained pace of accumulating capabilities as reflected in their positive ECIs.

From Figure 4, Ghana's accumulated capabilities over the years as reflected in the evolution of its ECIs for the period 1995 to 2016 have been quite uneven with no discernible pattern. It would be recalled that after the implementation of the Economic Recovery Programme (ERP) and Structural Adjustment Programme (SAP) in Ghana, the period 1992 to 1998, was when there was some relative macroeconomic stability and that might have translated into improved ECI around that period. However, the deterioration of external conditions in 1999 subsequently triggered sharp declines in Ghana's ECI. In addition, some improved macroeconomic conditions between 2009 and 2013 impacted positively on Ghana's ECI. However, the energy supply shock in 2014, coupled with external shocks, negatively impacted its ECI in 2015.
In general, the average ECIs for the countries in the East Asia & Pacific region have been on an upward trajectory whilst the averages for both the SSA region and ECOWAS sub-regions are on a downward path.

A possible explanation could be that countries in the East Asia & Pacific regions exerted considerable efforts at scaling up the levels of capabilities to be in the position to produce diverse and possibly less ubiquitous products. This could explain why in general most of the countries in East Asia and Pacific countries perform better in terms of export diversification and economic growth than their counterparts in the SSA region and the ECOWAS sub-region.



Source: Author's construct, 2019

3.3 Analysis of Ghana's Revealed Comparative Advantage (RCA)

As stated above, the concept of revealed comparative advantage can be used to highlight the systemic importance of a product in a country's export basket relative to the global significance of that product and the extent of diverse products that a country can produce. Hence, a country is said to have a revealed comparative advantage in a product if the calculated RCA is greater than one.

Table 1 presents the number of products that Ghana had RCA greater than one, in the years 2000 and 2016; the product community categorises into which they belong; as well as the associated export values and their relative shares in total export.

Table 1: Ghana's Export Products with RCA (2000 & 2016)

	2000			2016			
Commodity Community	Number of Products Ghana has RCA>1	Value of Ghana's Exports (US$' 000)	% of Ghana's Merchandised Exports	Number of Products Ghana has RCA>1	Value of Ghana's Exports (US$' 000)	% of Ghana's Merchandised Exports	Total Number of Products in category
Animal & animal products	3	26,500.0	1.5	2	30,000.0	0.2	44
Vegetable products	21	77,000.0	4.4	16	964,023.8	8.0	101
Foodstuffs	11	542,000.0	30.9	12	2,891,602.9	23.9	56
Mineral products	7	165,000.0	9.4	6	1,448,300.0	12.0	66
Chemicals & allied industries	6	5,055.1	0.3	5	76,072.8	0.6	176
Plastics/rubbers	2	8,010.9	0.5	4	310,000.0	2.6	43
Wood & wood products	14	195,000.0	11.1	5	320,000.0	2.6	68
Textiles/clothing	4	15,700.0	0.9	1	7,400.0	0.1	149
Footwear/headgear	1	19.3	0.0	1	650.2	0.0	20
Stone/glass	5	483,000.0	27.6	4	5,422,269.0	44.8	67
Metals	8	156,000.0	8.9	8	146,500.0	1.2	157
Machinery/electrical	1	4,734.8	0.3	1	38,000.0	0.3	133
Miscellaneous	4	1,846.9	0.1	1	403.7	0.0	101
Total	**87**	**1,679,867.0**	**95.8**	**66**	**11,655,222.4**	**96.3**	**1181**

Source: Author's Calculations using Export data at the HS4 level from Atlas of Economic Complexity Website

Source: Author's construct using data from Atlas of Economic Complexity Website, 2019

In 2000, Ghana had RCA in 87 products with an export value of about US$1.68 billion, constituting 95.8 percent of the total export of goods[8]. The number of products in which Ghana had RCA declined to 66 in 2016, with an export value of about US$11.65 billion, representing some 96.3 percent of total merchandised exports. This suggests that Ghana managed to improve on its share of the global trade in value terms over the past sixteen years. However, this was achieved on the back of increased export concentration exposing the country to potential vulnerabilities from changes in the world prices of these few products.

Comparing the two periods, Ghana was generally diversified in the production and export of vegetable products and foodstuffs. In 2016, the main products in the vegetable products category were coconuts, Brazilian nuts and Cashew nuts totalling

[8] The last column depicts the number of products exported globally in that product community category

US$600 million whilst that in the foodstuff category was cocoa beans totalling US$2.1 billion. The product with the highest export value was in the stone/glass category, and this was gold, totalling US$5.0 billion, whereas in the minerals category there was crude petroleum amounting to US$1.2 billion.

Table 2 presents the extent of product diversification among the countries in the ECOWAS sub-region. The indicators demonstrate a low level of export diversification for countries in the sub-region, although, Ghana's export basket was more diversified than eleven of the countries except for Senegal, Togo, and Benin. Almost all the countries were more diversified in the vegetable products and foodstuff categories, with a few diversified in the export of products in the chemicals and allied products and metals categories. This could expose the sub-region to common external shocks demanding some common approach to diffuse such potential threats.

Table 2: Number of Export Products with RCA, Ghana, and ECOWAS countries (2016)

	Ghana	Senegal	Togo	Mali	Guinea	Cote D'Voire	Gambia	Benin	Nigeria	Burkinafoso
Animal & animal products	2	10	4	6	3	0	5	4	3	3
Vegetable products	16	27	18	6	11	15	7	31	7	18
Foodstuffs	12	16	13	6	3	15	3	8	6	0
Mineral products	6	12	9	1	3	8	2	3	9	4
Chemicals & allied industries	5	18	13	10	0	3	2	3	0	0
Plastics/rubbers	4	2	4	1	1	1	0	2	1	0
Raw hides, skins, leather & furs	5	4	5	4	1	2	0	2	5	1
Wood & wood products	0	5	3	2	1	7	2	6	2	0
Textiles/clothing	1	7	10	8	2	3	2	5	0	2
Footwear/headgear	1	2	2	1	0	0	0	0	2	0
Stone/glass	4	1	3	1	1	1	2	3	0	1
Metals	8	18	11	2	3	4	4	14	6	1
Machinery/electrical	1	2	5	1	0	0	2	3	0	0
Transportation	0	1	4	2	0	0	0	1	1	0
Miscellaneous	1	6	0	4	1	1	3	0	0	0
Total	66	131	104	55	30	60	34	85	42	30

Source: Author's Calculations using Export data at the HS4 level from Atlas of Economic Complexity Website

3.4 How Ghana's RCAs have evolved between the years 2000 and 2016 by adopting a categorisation scheme of the RCAs

One of the core hypotheses that this paper seeks to explore is that the nature of products constituting a country's export basket matters for both current and future export diversification drive. Therefore, it becomes imperative to seek ways to assess both the current level of sophistication of products exported by Ghana and how that can translate into future opportunities in new strategic sectors. To accomplish this, the study adopted an in-sample analysis approach by Fortunato et al., (2015). According to this approach, RCAs are categorised into four groups based on how they have evolved between two periods (in this case 2000 and 2016)[9]. The groups are referred to as *emerging*, *established*, *underdeveloped* and *losing out*. The *emerging* group is used to represent products that Ghana did not have RCA (RCA<1) in 2000 but managed to secure RCA in 2016 (RCA>1). The *established* group contains products that Ghana did have RCA in 2000 (RCA>1) and continues to have RCA in 2016 (RCA>1). The *underdeveloped* group refers to products that Ghana did not have RCA in 2000 (RCA<1) and continues not to have RCA in 2016 (RCA< 1). Lastly, the *losing out* group captures products that Ghana used to have RCA (RCA>1) but is no more having RCA in 2016 (RCA<1)[10].

The above categorisation is compared with the level of product sophistication as measured by the Product Complexity Index (PCI) and the value of exports. The idea here is that products with higher PCI have better prospects in opening paths to new products. Production and export of a lot of products with high PCI could potentially prop up the growth of an economy in terms of promoting both forward and backward linkages, minimise the coordination problems related to deficits in capabilities to move

[9] With the dataset ending at 2016, we selected the start period of 2000 to be the same as the period selected for the first empirical paper. We also chose that period, to ensure that we get sufficient years for productive knowledge to be embedded and open new paths for diversification. Also, given that a similar study by Chandra, V., Osorio-Rodarte (2007) employed data for the periods 1980-84 to 2000-04, we decided to consider a relatively more current period, 2000-2016, to update the literature.

[10] It will be noted that, I did a similar categorization by comparing the averages of RCAs for the period 2000-2004 to that of 2012-2016, instead of comparing the years 2000 and 2016. However, since there was not significance material difference between the two categorizations, I stuck to the later for the purpose of analysis.

into new products, and ultimately facilitating the country's structural transformation strategy. This analysis is done initially by using graphs. Subsequently, cross-tabs of the categories with the product community groups are generated to examine the sectors that emerged because of changes in the RCAs over the 16 years.

For the purpose of this analysis, Ghana and Nigeria are placed on one side (representing the ECOWAS sub-region) and compare to Malaysia and Singapore on the other side (representing the East Asia & Pacific region). The exercise reveals the sectors that contributed to the successes of the countries in the East Asia & Pacific region in their export diversification drive as against that of the countries in the ECOWAS sub-region, especially Ghana.

Figure 5 presents four graphs in a quadrant for the four countries. In each graph, the categories for the RCAs between the years 2000 and 2016 are compared with the level of PCIs and the values of exports.

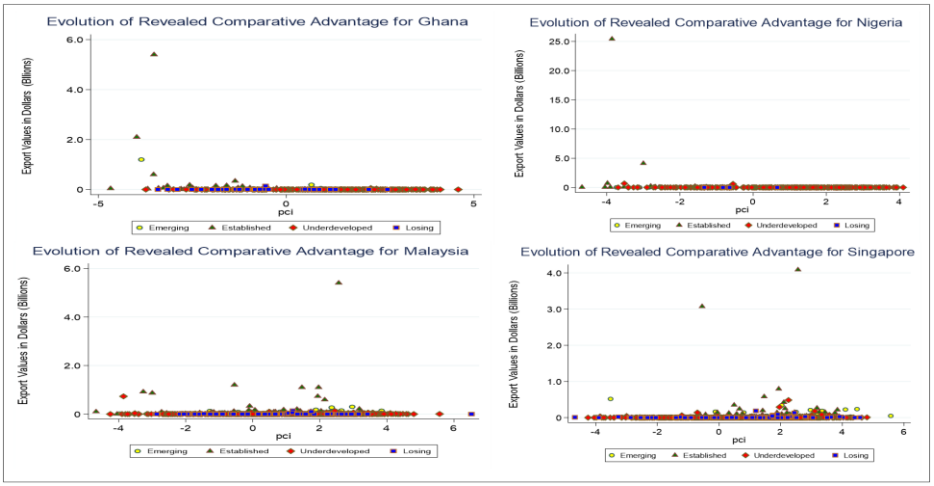
From Figure 5, both Ghana and Nigeria are established in the production and export of products with exceptionally low PCIs and these products largely fetched the highest export values[11]. Ghana is highly established in the production of gold, cocoa, and coconuts & Brazil nuts & cashew with PCIs of -3.518, -3.978 and -3.595, respectively. This suggests that Ghana has built capabilities in products with low sophistication and weak linkage possibilities to other sectors. A similar commentary can be made of Nigeria, which is also established in products with relatively low PCIs. The three products with the highest export values that Nigeria is established in are crude petroleum, petroleum gas and cocoa with PCIs of -3.856, -2.998 and -3.978, respectively.

Examining both countries, most of the high-value products that emerged because of their respective acquired capabilities over the years, equally tended to have low levels of sophistication as reflected in their PCIs. However, the average PCIs for the

[11] Indeed, due to the large number of products involved, for all the respective country analysis, we will select the three export products that fetch the highest values in the country's export basket. The rest of the statistics are summarised in the cross-tabs below.

emerging products in both countries tend to be relatively higher than that for the established products, though Ghana seems to be more complex than Nigeria[12]. For instance, the highest three products that emerged in Ghana's export basket were crude petroleum, plastic lids, and other inorganic acids with PCIs of -3.856, 0.672 and 0.923, respectively. This can be compared with the emerging products in Nigeria's export basket, which are scrap copper, raw lead, and cement also with PCIs of -1.2682, -1.3963 and -1.5726, respectively. In the case of Ghana, the emerged products with positive PCIs offer some glimmer of hope in terms of new paths leading to other products with possibly higher PCIs likely to aid the country's structural transformation and export diversification drive.

Figure 5: Evolution of Revealed Comparative Advantage of Selected Countries (bet.2000 and 2016)



Source: Author generated, 2019

[12] The average PCI for the established products category for Ghana and Nigeria are -1.88323 and -2.65503, whilst that for the emerging products category are -0.28575 and -1.80466 respectively. This suggests that the countries are increasing the levels of product sophistication with the expansion of their export basket to secure RCA in new products. The same holds for the two East Asian countries. Singapore and Malaysia have average PCI levels for their established products to be 1.32587 and 0.505138, but that for the emerging products are 2.5334 and 1.056995, respectively.

Unfortunately, Ghana appeared to be losing out in products that have relatively higher PCIs than the ones associated with the established products. Ghana lost out in the export of products such as refined petroleum, electricity and other processed fruits and nuts amongst others with PCI levels of – 0.5481, 0.5025 and – 1.341, respectively. Similarly, Nigeria lost out on relatively higher PCI products such as precious stones (-1.3328), other vegetable residues (-0.6422), and processed bones (0.6584).

The evidence for Malaysia and Singapore is different from those for Ghana and Nigeria. From Figure 5, both countries are largely established in products with relatively high PCIs. Singapore is established in the export of products such as integrated circuits, refined petroleum, and computers with PCI levels of 2.5619, -0.5481 and 1.9372, respectively. In a similar vein, Malaysia is established in the production and export of integrated circuits, refined petroleum, and telephones with PCI levels of 2.5619, -0.5481 and 1.9372, respectively. It is, therefore, not surprising that these two countries are in the league of countries that have made tremendous achievements in export-led growth both based on export diversification and the level of sophistication of export products, with high potential for opening up new paths for further growth. In the emerging products category, both countries tend to export products with relatively high PCIs. For Singapore, some of the emerging products in its export basket are gold, gas turbines and chemical analysis instruments with PCI levels of -3.5182, 2.0349 and 4.1005, respectively. On the other hand, Malaysia's export basket has emerging products such as industrial printers, oscilloscopes, and low voltage protection equipment with PCI levels of 2.9653, 2.3524 and 1.8817, respectively.

Singapore lost RCA in products such as broadcasting equipment, medical instruments, and passenger & cargo ships with PCI levels of 1.1980, 2.4447 and 1.9064, respectively. At the same time, Malaysia equally lost RCA in products such as broadcasting equipment, electrical transformer, and seats with PCI levels of 1.1980, 17438 and 1.1891, respectively. Both Singapore and Malaysia lost RCA in products with average PCI levels of 0.9772 and 0.6423, respectively. It would be noted that both Singapore and Malaysia lost RCA in products with average levels of PCI (average sophistication level) lower than the average levels of PCI for the emerging RCA

products. Though a similar pattern is seen in the case of Ghana, the same did not happen for Nigeria[13]. This suggests that initial conditions in terms of the number of products with RCAs and their average PCI levels count a lot for the PCI levels for the emerging RCA products. From the analysis above, countries that initially had RCA in a lot of products and a high average level of PCI tend to increase the average level of PCI for the emerging RCA products.

Table 3 presents the product community or the sectors experiencing these evolutions in the RCA[14]. From the analytical tables, one can deduce some implications for a country's structural transformation effort. In general, Ghana and Nigeria established RCA largely in the vegetables, foodstuffs and mineral sectors, suggesting that not much has been achieved over the years in scaling up value addition in the other sectors which tended to have huge potential for industrialization. In contrast, Singapore and Malaysia established RCA in the machinery/electrical, chemicals & allied, and miscellaneous sectors. The extent of capabilities acquired from these sectors would be solid enough to deploy to a lot more sectors, unlike the case of Ghana and Nigeria. Consistently, Ghana and Nigeria have emerging RCAs in the foodstuff, vegetables, minerals, and metals sectors, unlike Singapore and Malaysia that have emerging RCA in the chemical and allied, machinery/electrical, metals, and miscellaneous sectors.

[13] The average level of PCI for the products losing RCA for Singapore and Malaysia are 0.97723 and 0.64228 compared with the average level of PCI for the emerging products are 2.5334 and 1.056995 respectively.
However, the average level of PCI for the losing RCA products for Ghana and Nigeria are -0.417045 and -0.241374 compared with emerging products category of -0.28575 and -1.80466 respectively

[14] A product community is considered as a group of products that require related productive knowledge

Table 3: Product Community and Evolution of Revealed Comparative Advantage Categories of Selected Countries

Ghana

	Emerging	Established	Underdeveloped	Losing	Total
Animal & animal products	0	2	41	1	44
Chemicals & allied ..	4	1	166	5	176
Foodstuffs	4	8	41	3	56
Footwear/headgear	1	0	18	1	20
Machinery/electrical	0	1	132	0	133
Metals	4	4	145	4	157
Mineral products	2	4	57	3	66
Miscellaneous	0	1	97	3	101
Plastics/rubbers	2	2	39	0	43
Raw hides, skins, l..	0	0	21	0	21
Stone/glass	3	1	59	4	67
Textiles/clothing	1	0	144	4	149
Transportation	0	0	38	0	38
Vegetable products	5	11	75	10	101
Wood & wood products	0	5	54	9	68

Nigeria

	Emerging	Established	Underdeveloped	Losing	Total
Animal & animal products	1	2	40	1	44
Chemicals & allied ..	0	0	176	0	176
Foodstuffs	2	4	49	1	56
Footwear/headgear	2	0	18	0	20
Machinery/electrical	0	0	133	0	133
Metals	5	1	150	1	157
Mineral products	5	4	57	0	66
Miscellaneous	0	0	101	0	101
Plastics/rubbers	0	1	42	0	43
Raw hides, skins, l..	2	3	16	0	21
Stone/glass	0	0	66	1	67
Textiles/clothing	0	0	149	0	149
Transportation	1	0	37	0	38
Vegetable products	2	5	94	0	101
Wood & wood products	0	2	65	1	68

Singapore

	Emerging	Established	Underdeveloped	Losing	Total
Animal & animal products	0	3	41	0	44
Chemicals & allied ..	19	22	123	12	176
Foodstuffs	2	5	45	4	56
Footwear/headgear	0	0	20	0	20
Machinery/electrical	11	24	85	13	133
Metals	9	8	127	13	157
Mineral products	2	4	57	3	66
Miscellaneous	17	13	66	5	101
Plastics/rubbers	3	8	29	3	43
Raw hides, skins, l..	0	1	19	1	21
Stone/glass	8	1	55	3	67
Textiles/clothing	3	0	139	7	149
Transportation	4	4	28	2	38
Vegetable products	0	6	89	6	101
Wood & wood products	3	3	57	5	68

Malaysia

	Emerging	Established	Underdeveloped	Losing	Total
Animal & animal products	0	4	39	1	44
Chemicals & allied ..	14	8	149	5	176
Foodstuffs	5	7	42	2	56
Footwear/headgear	0	0	19	1	20
Machinery/electrical	17	23	87	6	133
Metals	15	16	119	7	157
Mineral products	9	6	50	1	66
Miscellaneous	11	8	72	10	101
Plastics/rubbers	5	7	29	2	43
Raw hides, skins, l..	0	0	20	1	21
Stone/glass	10	6	46	5	67
Textiles/clothing	7	5	119	18	149
Transportation	1	1	36	0	38
Vegetable products	5	10	82	4	101
Wood & wood products	4	9	51	4	68

Source: Author generated,2019

It would be noted that both Ghana and Nigeria lost RCA in products they used to have RCA, but in the case of Ghana, the unfortunate commentary is that it lost RCA in some products in the chemical and allied and textiles sectors with many potentials for enhancing the export diversification drive. This could be attributed largely to the stiff competition from relatively cheaper alternatives from China and the high costs of doing business in Ghana (especially the costs, availability, and reliability of electricity in Ghana)[15]. Ghana and Nigeria have a lot more products with underdeveloped RCAs

[15] According the World Bank's Ease of Doing Business Survey for 2018, Ghana is ranked 120 out of 190 countries, Nigeria is ranked 145, Singapore is ranked 2 and Malaysia is ranked 24. According to the same

than Singapore and Malaysia. It could be suggested that Ghana and Nigeria have more room to improve on their average level of sophistication provided they could take the paths that countries like Singapore and Malaysia took.

3.5 Selection of New Products within Ghana's Knowledge Frontier

To operationalise the evolution of Ghana's ECI within the Product Space construct, an approach by Hausmann and Jasmina (2015) that involved a combination of the concept of ECI, the measures of Distance and Opportunity Gain was adopted to identify new products reflecting more diverse and attractive product mix (otherwise referred to as "frontier" products) for Ghana, given its current productive knowledge.

To further explore the possibility of developing the "frontier products" to target the ECOWAS sub-region market and the global market, the study developed an indicator of import intensity for the ECOWAS sub-region. The indicator was developed by using the same theoretical concept supporting the revealed comparative advantage analysis[16]. After this, the "frontier products" identified within Ghana's current productive knowledge are compared with those products that are intensively imported in the sub-region to guide Ghana's effort at targeting that market effectively, provided it has the competitive urge.

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report, Ghana is ranked 136 on the matric of getting electricity, Nigeria is ranked 172, Singapore is ranked 12 and Malaysia is ranked 8. Refer to Appendix tables

[16] Here we use the same formula for RCA applied to export, but in this case for imports. Therefore, we compare the average imports of a particular product by the ECOWAS sub-region to the total imports by the Sub-region and the total import of that particular product to world trade. The ratio gives us the intensity indicator. $RCA_{cp} = \dfrac{\dfrac{M_{cp}}{\sum_c M_{cp}}}{\dfrac{\sum_p M_{cp}}{\sum_{c,p} M_{cp}}}$

where M represents imports and c in this case represents ECOWAS countries and the rest as explained above.

Hence for a particular product if the calculated RCA is greater than one, then we conclude that the sub-region has RCA in the importation of that product and for that reason the product is intensively imported.

According to Hausmann and Jasmina (2015) the "frontier products" must satisfy the criteria that: (i) the level of product sophistication must exceed the average associated with a particular country's current export basket (in this case Ghana's ECI); (ii) the products are within the country's feasible region, given its productive knowledge; and (iii) the products will aid further export diversification efforts in the future. Hence, the optimal condition is that countries diversify into new products with high PCI, closest Distance, and the highest Opportunity gain. Notwithstanding, these three ideal conditions may not always converge. Often, products with higher PCI may lie at a distance further from the current productive knowledge, which may deepen the coordination problem.

For the practical implementation of this approach, the following order of sequencing is adopted to identify the "frontier" products:

(1) We eliminate all products (that Ghana does not have RCA) with PCI values below the average PCI of all existing products in Ghana's export basket. The residual products have PCIs either equal or above the average PCI for Ghana's current export basket and are likely to augment the level of sophistication of Ghana's export basket.

(2) To identify products that are feasible within the proximity of Ghana's current productive knowledge, we use the measure of distance, where the closer the distance measure, the more preferable the product. In this case, it has been argued that whilst there may be no threshold for the measure of distance, it must be possible for the widest distance to be narrowed with enough investment. Thus, for this exercise, the median distance of products that Ghana did not have RCA was used as the threshold.

(3) Like the above, we use the mean of the measure of opportunity gain (where values above the mean are preferable) to eliminate products that do not have prospects of opening new paths for export diversification.

After executing the above procedure, Tables 4a, b and c present Ghana's identified frontier products. About 131 products are identified, but this list is reduced to 91 to

exclude products with export values less than US$1,000. From the two tables one can observe the PCIs of the products identified; their closeness to Ghana's export basket represented by the Distance measure; the Complexity Outlook values also reflecting the Opportunity gain measures; the values of export of each product both within Ghana's export basket and that of the ECOWAS region; the corresponding values of each product in terms of the imports into the ECOWAS region and global trade; finally the sectors for each product represented by the product community (pointing to the similarity in terms of the requisite capabilities needed for products within that cluster) and the Lall classification, pointing to the level of technology embedded in each product. It is observed that the average levels of sophistication of the identified products as represented by the PCIs are greater than one.

In Table 1, we reported that Ghana had RCA in 66 products out of the 892 products (of the global total of 1241 products) it exported in 2016. These products had a share of 96.3 percent of the total export value in 2016. The average level of PCI for the 66 products is negative 1.254, suggesting a low level of complexity and for that matter sophistication with weak prospects for structural transformation and diversification.

A different picture is emerging from Table 4a, b & c, suggesting that for the 91 frontier products, which though Ghana does not have RCA yet, but are feasible within its current productive knowledge and constitute about 1.07 percent of the total export value for 2016, the average level of PCI is 1.696. This implies that the frontier products possess high level of sophistication and strategic value, with the potential for enhancing the structural transformation of the Ghanaian economy if they are exploited and developed for export. Especially, by considering the sectors emerging from the frontier products; their strategic location within the product space and their potential to drive the structural transformation and export diversification agenda. A shift from focusing on foodstuff and vegetable products to chemicals & allied industries, machinery/electricals, plastics and metals among others, which are more technology-inclined and have the complex network structures that can help to create further industries to diversify Ghana's export basket.

Table 4a: Products identified within Ghana's productive knowledge (using 2016 export basket)[17]

Products	PCI	DISTANCE	OPGAIN	EXPORT VALUE (US$)	ECOWAS EXPORTS (US$)	ECOWAS IMPORTS (US$)	WORLD IMPORTS (US$)	PRODUCT COMMUNITY	LALL CLASSIFICATION
Pig Meat	2.3212	0.9563	0.9338	43,978	234,748	18,000,000	26,000,000,000	Animal & animal products	Processed
Whey	2.0371	0.9542	0.8334	9,958	2,600,000	16,000,000	3,700,000,000	Animal & animal products	Processed
Packaged Medicaments	2.2539	0.9533	0.8390	56,000,000	71,000,000	2,300,000,000	320,000,000,000	Chemicals & allied industries	HT2: Other high technology
Beauty Products	2.4039	0.9561	1.0107	27,000,000	92,000,000	160,000,000	38,000,000,000	Chemicals & allied industries	MT2: Process industries
Pesticides	1.7941	0.9505	0.7627	2,000,000	9,200,000	570,000,000	30,000,000,000	Chemicals & allied industries	MT2: Process industries
Cleaning Products	1.0548	0.9389	0.5322	1,700,000	18,000,000	230,000,000	29,000,000,000	Chemicals & allied industries	MT2: Process industries
Nonaqueous Paints	1.4649	0.9457	0.7254	1,600,000	8,400,000	100,000,000	12,000,000,000	Chemicals & allied industries	MT2: Process industries
Perfumes	1.1586	0.9499	0.6542	994,397	12,000,000	52,000,000	15,000,000,000	Chemicals & allied industries	MT2: Process industries
Industrial Fatty Acids, Oils and Alcohols	2.2700	0.9534	1.0209	934,871	4,400,000	150,000,000	44,000,000,000	Chemicals & allied industries	Semi-processed
Chlorides	1.3586	0.9552	0.7376	498,284	555,498	12,000,000	2,100,000,000	Chemicals & allied industries	RB2: Other resource based products
Dental Products	1.3138	0.9487	0.5478	427,660	1,800,000	66,000,000	4,800,000,000	Chemicals & allied industries	MT2: Process industries
Aqueous Paints	1.6600	0.9465	0.6852	345,748	2,500,000	33,000,000	5,400,000,000	Chemicals & allied industries	MT2: Process industries
Organic Composite Solvents	1.0247	0.9418	0.6206	318,986	901,272	27,000,000	1,400,000,000	Chemicals & allied industries	MT2: Process industries
Sodium or Potassium Peroxides	1.0718	0.9553	0.7823	307,610	2,100,000	94,000,000	4,700,000,000	Chemicals & allied industries	RB2: Other resource based products
Saturated Acyclic Monocarboxylic Acids	2.2857	0.9568	0.9104	125,833	349,686	42,000,000	12,000,000,000	Chemicals & allied industries	MT2: Process industries
Carbon	1.3941	0.9557	0.7136	106,818	120,046	2,500,000	3,200,000,000	Chemicals & allied industries	RB2: Other resource based products
Glaziers Putty	1.9061	0.9487	0.7730	98,799	484,299	40,000,000	7,000,000,000	Chemicals & allied industries	MT2: Process industries
Polishes and Creams	1.2663	0.9482	0.7245	56,424	369,555	18,000,000	2,000,000,000	Chemicals & allied industries	MT2: Process industries
Antifreeze	1.8290	0.9522	0.7853	54,740	78,932	7,100,000	1,100,000,000	Chemicals & allied industries	MT2: Process industries
Nitric Acids	1.8471	0.9536	0.7867	51,895	60,193	1,300,000	280,000,000	Chemicals & allied industries	RB2: Other resource based products
Carbides	1.1737	0.9566	0.5160	30,355	76,686	12,000,000	1,700,000,000	Chemicals & allied industries	RB2: Other resource based products
Dyeing Finishing Agents	1.2524	0.9508	0.6345	13,748	122,561	6,200,000	4,000,000,000	Chemicals & allied industries	Semi-processed
Other Paints	1.4654	0.9468	0.6616	11,013	243,171	10,000,000	740,000,000	Chemicals & allied industries	MT2: Process industries
Bandages	2.4226	0.9561	1.0353	2,502	139,941	34,000,000	7,100,000,000	Chemicals & allied industries	HT2: Other high technology
Chocolate	1.4971	0.9439	0.5812	6,100,000	150,000,000	55,000,000	25,000,000,000	Foodstuffs	Semi-processed
Beer	0.9675	0.9458	0.5076	284,260	9,200,000	62,000,000	14,000,000,000	Foodstuffs	Processed
Other Fermented Beverages	1.6849	0.9457	0.6002	270,569	376,346	6,300,000	1,400,000,000	Foodstuffs	Processed
Other Frozen Vegetables	0.9807	0.9556	0.5519	96,343	260,725	12,000,000	7,200,000,000	Foodstuffs	Processed
Excavation Machinery	2.2016	0.9513	0.8795	6,800,000	33,000,000	570,000,000	47,000,000,000	Machinery/electrical	MT3: Engineering industries
Telephones	1.9617	0.9539	0.7313	3,300,000	23,000,000	930,000,000	280,000,000,000	Machinery/electrical	HT1: Electronics and electrical products

Source: Author's construct, 2019

[17] The median for the Distance measure is 0.95678 and the Means for the PCI and OPPGAIN measures are 0.9115 and 0.4926, respectively.

Table 4b: Products identified within Ghana's productive knowledge (using 2016 export basket), (cont'd)

Products	PCI	DISTANCE	OPGAIN	EXPORT VALUE (US$)	ECOWAS EXPORTS (US$)	ECOWAS IMPORTS (US$)	WORLD IMPORTS (US$)	PRODUCT COMMUNITY	LALL CLASSIFICATION
Electrical Transformers	1.7438	0.9565	0.7322	388,773	3,200,000	470,000,000	83,000,000,000	Machinery/electrical	HT1: Electronics and electrical products
Low-voltage Protection Equipment	1.8817	0.9542	0.8746	131,698	2,800,000	270,000,000	89,000,000,000	Machinery/electrical	MT3: Engineering industries
Navigation Equipment	2.2905	0.9562	1.0464	66,287	384,281	27,000,000	19,000,000,000	Machinery/electrical	HT1: Electronics and electrical products
Electric Heaters	1.9058	0.9567	0.5937	36,954	830,185	99,000,000	41,000,000,000	Machinery/electrical	MT3: Engineering industries
Water and Gas Generators	1.7626	0.9523	0.7515	19,016	335,492	80,000,000	840,000,000	Machinery/electrical	MT3: Engineering industries
Other Iron Products	2.3390	0.9535	0.7910	2,200,000	11,000,000	320,000,000	41,000,000,000	Metals	LT2: Other low technology
Iron Cloth	1.4616	0.9515	0.5969	1,900,000	2,500,000	52,000,000	3,900,000,000	Metals	LT2: Other low technology
Iron Structures	1.6550	0.9413	0.5147	1,400,000	24,000,000	680,000,000	41,000,000,000	Metals	LT2: Other low technology
Hot-Rolled Iron Bars	1.4753	0.9491	0.6281	1,000,000	7,000,000	160,000,000	8,100,000,000	Metals	LT2: Other low technology
Other Cast Iron Products	1.4855	0.9549	0.5615	322,762	395,831	42,000,000	5,800,000,000	Metals	LT2: Other low technology
Aluminium Structures	1.5980	0.9442	0.5287	231,280	512,517	110,000,000	10,000,000,000	Metals	LT2: Other low technology
Aluminium Bars	1.4349	0.9482	0.5009	157,624	448,232	200,000,000	17,000,000,000	Metals	Other primary products
Large Flat-Rolled Iron	2.1174	0.9533	0.8482	146,790	1,400,000	15,000,000	3,600,000,000	Metals	LT2: Other low technology
Small Iron Containers	1.1318	0.9398	0.5197	117,191	4,300,000	39,000,000	5,500,000,000	Metals	LT2: Other low technology
Other Iron Bars	1.7205	0.9531	0.6454	58,715	7,000,000	24,000,000	2,100,000,000	Metals	LT2: Other low technology
Coated Metal Soldering Products	1.5997	0.9490	0.6352	15,283	303,718	53,000,000	2,700,000,000	Metals	LT2: Other low technology
Metal Stoppers	1.5474	0.9513	0.6409	11,792	1,900,000	56,000,000	5,800,000,000	Metals	LT2: Other low technology
Iron Sheet Piling	1.5507	0.9500	0.6599	9,293	602,038	14,000,000	1,800,000,000	Metals	LT2: Other low technology
Metal Signs	1.3090	0.9493	0.6309	4,872	114,306	6,500,000	640,000,000	Metals	LT2: Other low technology
Copper Bars	1.0831	0.9486	0.5815	4,244	89,085	4,800,000	4,500,000,000	Metals	Other primary products
Chalk	1.2177	0.9538	0.7061	5,696	175,729	1,500,000	150,000,000	Mineral products	Other primary products
Granulated Slag	1.2569	0.9554	0.5094	2,277	2,277	5,600,000	580,000,000	Mineral products	Other primary products
Optical Fibers	2.2055	0.9565	0.8630	1,700,000	2,000,000	13,000,000	26,000,000,000	Misscelaneous	HT2: Other high technology
Surveying Equipment	2.2749	0.9550	0.9723	792,308	4,000,000	47,000,000	7,000,000,000	Misscelaneous	HT2: Other high technology
Prefabricated Buildings	1.4512	0.9447	0.5003	745,489	6,000,000	160,000,000	7,300,000,000	Misscelaneous	RB1: Agro/forest based products
Opto-Electric Instrument Parts	2.5722	0.9555	1.0058	31,762	63,331	53,000,000	2,800,000,000	Misscelaneous	HT2: Other high technology
Military Weapons	1.9048	0.9548	0.6487	21,317	31,000,000	190,000,000	1,200,000,000	Misscelaneous	MT3: Engineering industries
Ink Ribbons	2.1750	0.9555	1.0516	3,497	33,463	7,400,000	1,600,000,000	Misscelaneous	LT2: Other low technology
Other Plastic Sheetings	2.0672	0.9458	0.7702	2,700,000	8,500,000	100,000,000	22,000,000,000	Plastics/rubbers	MT2: Process industries
Raw Plastic Sheeting	1.3025	0.9402	0.5483	1,400,000	14,000,000	250,000,000	51,000,000,000	Plastics/rubbers	MT2: Process industries

Source: Author's construct, 2019

Table 4c: Products identified within Ghana's productive knowledge (using 2016 export basket) (cont'd)

Products	PCI	DISTANCE	OPGAIN	EXPORT VALUE (US$)	ECOWAS EXPORTS (US$)	ECOWAS IMPORTS (US$)	WORLD IMPORTS (US$)	PRODUCT COMMUNITY	LALL CLASSIFICATION
Plastic Building Materials	1.8630	0.9487	0.6259	1,000,000	1,500,000	73,000,000	9,300,000,000	Plastics/rubbers	LT2: Other low technology
Other Rubber Products	2.5003	0.9558	0.9897	199,166	1,200,000	67,000,000	24,000,000,000	Plastics/rubbers	RB1: Agro/forest based products
Used Rubber Tires	1.1431	0.9509	0.6491	109,584	620,635	46,000,000	2,400,000,000	Plastics/rubbers	RB1: Agro/forest based products
Plastic Wash Basins	1.7683	0.9528	0.6912	28,435	73,276	29,000,000	3,400,000,000	Plastics/rubbers	LT2: Other low technology
Rubber Sheets	2.5610	0.9553	1.0229	18,005	164,031	21,000,000	3,500,000,000	Plastics/rubbers	RB1: Agro/forest based products
Rock Wool	2.8275	0.9554	1.0976	48,594	346,999	11,000,000	3,700,000,000	Stone/glass	RB2: Other resource based products
Asbestos Cement Articles	1.3486	0.9437	0.5341	45,053	814,432	8,600,000	1,100,000,000	Stone/glass	RB2: Other resource based products
Friction Material	1.2546	0.9566	0.8370	5,981	14,367	9,700,000	1,400,000,000	Stone/glass	RB2: Other resource based products
Glass Fibers	2.2210	0.9554	0.7970	2,325	167,892	13,000,000	11,000,000,000	Stone/glass	RB2: Other resource based products
Cement Articles	2.0893	0.9512	0.7986	1,600	250,539	79,000,000	7,700,000,000	Stone/glass	RB2: Other resource based products
Vegetable Fiber	1.6062	0.9495	0.6097	1,002	12,976	2,600,000	390,000,000	Stone/glass	RB2: Other resource based products
Synthetic Monofilament	1.5746	0.9543	0.8259	170,427	352,356	20,000,000	1,200,000,000	Textiles/clothing	LT1: Fashion cluster
Non-Retail Synthetic Filament Yarn	1.4077	0.9508	0.5369	46,741	245,169	49,000,000	16,000,000,000	Textiles/clothing	LT1: Fashion cluster
Buses	1.5740	0.9503	0.6409	401,132	3,000,000	420,000,000	16,000,000,000	Transportation	MT1: Automotive products
Trailers	2.5090	0.9552	0.9216	217,584	5,600,000	220,000,000	22,000,000,000	Transportation	MT2: Process industries
Tractors	2.0854	0.9567	0.8545	151,717	6,300,000	380,000,000	42,000,000,000	Transportation	MT3: Engineering industries
Recreational Boats	1.2830	0.9504	0.5722	3,232	1,200,000	17,000,000	13,000,000,000	Transportation	MT3: Engineering industries
Rapeseed Oil	1.5465	0.9479	0.6101	45,940	63,161	1,700,000	6,100,000,000	Vegetable products	Semi-processed
Cereal Straws	1.0417	0.9545	0.5190	19,331	33,780	19,877	230,000,000	Vegetable products	Semi-processed
Corrugated Paper	2.0633	0.9541	0.8001	1,100,000	1,200,000	9,600,000	1,700,000,000	Wood & wood products	RB1: Agro/forest based products
Other Printed Material	1.7633	0.9476	0.7493	657,539	2,100,000	37,000,000	11,000,000,000	Wood & wood products	Other
Uncoated Paper	1.9595	0.9535	0.6552	258,045	796,372	200,000,000	18,000,000,000	Wood & wood products	RB1: Agro/forest based products
Brochures	1.1414	0.9504	0.6008	242,437	2,400,000	120,000,000	15,000,000,000	Wood & wood products	Other
Shaped Paper	1.7341	0.9557	0.8253	238,478	851,682	92,000,000	12,000,000,000	Wood & wood products	LT2: Other low technology
Letter Stock	1.2886	0.9441	0.5159	27,009	192,296	6,300,000	960,000,000	Wood & wood products	LT2: Other low technology
Cigarette Paper	1.1581	0.9497	0.6096	24,191	51,423	14,000,000	2,000,000,000	Wood & wood products	LT2: Other low technology
Particle Board	1.4124	0.9447	0.5428	10,221	11,399	6,300,000	7,200,000,000	Wood & wood products	RB1: Agro/forest based products
Wood Crates	1.6810	0.9403	0.5514	6,379	186,119	5,000,000	3,000,000,000	Wood & wood products	RB1: Agro/forest based products
Cellulose Fibers Paper	1.5471	0.9556	0.7632	5,692	131,657	170,000,000	13,000,000,000	Wood & wood products	RB1: Agro/forest based products
Other Uncoated Paper	1.1921	0.9469	0.5442	5,376	1,000,000	77,000,000	9,900,000,000	Wood & wood products	RB1: Agro/forest based products
Newspapers	2.3011	0.9520	0.8835	5,025	156,568	7,000,000	3,300,000,000	Wood & wood products	Other

Source: Author's construct, 2019

Flowing from the foregoing discussion, it may be imperative for Ghana to reexamine its priority products in the light of the frontier products identified to establish a clear strategic agenda for export promotion. This must be grounded on its current capabilities and possibilities, for which the level of sophistication of its export can be enhanced at minimal coordination costs. It is worth noting that the nature of such 'frontier' products is such that they have spillover effects in terms of the benefits, which can encourage free-riding tendencies, but the costs, especially the sunk costs associated with the discovery being borne solely by the inventor, can be discouraging more especially in situations of failure. Hence, some government intervention by way of a deliberate policy to encourage firms to innovate and invent could be the catalyst to ensure speedy maximisation of the benefits of investing in the development of these 'frontier' products.

One of the key limitations of this study is not considering the possibility of tariff escalation due to the relatively higher level of technology associated with the frontier products, which could make them not competitive. This issue could be partly addressed if Ghana can exploit the ECOWAS sub-region market and take advantage of the regime of the Common External Tariff prevailing, where some progress and subsequent gains can be accomplished. As indicated above, we calculated import intensities for each of the imported products for the ECOWAS sub-region in 2016, using the RCA concept, (Hausmann and Jasmina, 2015). Thus, in Table 1.5 we present the frontier products generated with the condition that the comparable import intensity (RCAm) for each product within the ECOWAS sub-region is greater one (RCAm > 1) and the total import value is also greater than US$1000. As a result, 50 frontier products are identified. It would be observed from Table 1.5 that whilst the ECOWAS sub-region export largely fruits and vegetables as well as primary products as previously indicated, their imports are largely high technology-oriented goods, processed goods, and automotive products, among others. However, the suggestion is that for these 50 frontier products, Ghana can develop and export them to the ECOWAS sub-regional market. This will promote the spirit of sub-regional trade and integration with the potential for enhancing industrialisation in the sub-region and opportunity for value addition and job creation.

The success of such a trade strategy would largely hinge on efforts at containing costs and reliability of logistics infrastructure within the sub-region as well as the requisite trade facilitation structures to minimise transaction costs and make the trade in the sub-region competitive.

Table 5a: 'Frontier' Products Capable of Engendering Regional Trade (Using 2016 Export Basket) and ECOWAS Import Intensity Indices

Products	PCI	DISTANCE	OPGAIN	RCAm	EXPORT VALUE (US$)	ECOWAS EXPORTS (US$)	ECOWAS IMPORTS (US$)	WORLD IMPORTS (US$)	PRODUCT COMMUNITY	LALL CLASSIFICATION
Packaged Medicaments	2.2539	0.9533	0.8390	1.1560	56,000,000	71,000,000	2,300,000,000	320,000,000,000	Chemicals & allied industries	HT2: Other high technology
Excavation Machinery	2.2016	0.9513	0.8795	1.9509	6,800,000	33,000,000	570,000,000	47,000,000,000	Machinery/electrical	MT3: Engineering industries
Other Iron Products	2.3390	0.9535	0.7910	1.2386	2,200,000	11,000,000	320,000,000	41,000,000,000	Metals	LT2: Other low technology
Pesticides	1.7941	0.9505	0.7627	3.0863	2,000,000	9,200,000	570,000,000	30,000,000,000	Chemicals & allied industries	MT2: Process industries
Iron Cloth	1.4616	0.9515	0.5969	2.1453	1,900,000	2,500,000	52,000,000	3,900,000,000	Metals	LT2: Other low technology
Cleaning Products	1.0548	0.9389	0.5322	1.2595	1,700,000	18,000,000	230,000,000	29,000,000,000	Chemicals & allied industries	MT2: Process industries
Nonaqueous Paints	1.4649	0.9457	0.7254	1.3632	1,600,000	8,400,000	100,000,000	12,000,000,000	Chemicals & allied industries	MT2: Process industries
Iron Structures	1.6550	0.9413	0.5147	2.6352	1,400,000	24,000,000	680,000,000	41,000,000,000	Metals	LT2: Other low technology
Plastic Building Materials	1.8630	0.9487	0.6259	1.2527	1,000,000	1,500,000	73,000,000	9,300,000,000	Plastics/rubbers	LT2: Other low technology
Hot-Rolled Iron Bars	1.4753	0.9491	0.6281	3.2710	1,000,000	7,000,000	160,000,000	8,100,000,000	Metals	LT2: Other low technology
Surveying Equipment	2.2749	0.9550	0.9723	1.0748	792,308	4,000,000	47,000,000	7,000,000,000	Misscelaneous	HT2: Other high technology
Prefabricated Buildings	1.4512	0.9447	0.5003	3.5464	745,489	6,000,000	160,000,000	7,300,000,000	Misscelaneous	RB1: Agro/forest based products
Dental Products	1.3138	0.9487	0.5478	2.1808	427,660	1,800,000	66,000,000	4,800,000,000	Chemicals & allied industries	MT2: Process industries
Buses	1.5740	0.9503	0.6409	4.3543	401,132	3,000,000	420,000,000	16,000,000,000	Transportation	MT1: Automotive products
Other Cast Iron Products	1.4855	0.9549	0.5615	1.1709	322,762	395,831	42,000,000	5,800,000,000	Metals	LT2: Other low technology
Organic Composite Solvents	1.0247	0.9418	0.6206	3.0734	318,986	901,272	27,000,000	1,400,000,000	Chemicals & allied industries	MT2: Process industries
Sodium or Potassium Peroxides	1.0718	0.9553	0.7823	3.2095	307,610	2,100,000	94,000,000	4,700,000,000	Chemicals & allied industries	RB2: Other resource based products
Uncoated Paper	1.9595	0.9535	0.6552	1.8057	258,045	796,372	200,000,000	18,000,000,000	Wood & wood products	RB1: Agro/forest based products
Brochures	1.1414	0.9504	0.6008	1.2721	242,437	2,400,000	120,000,000	15,000,000,000	Wood & wood products	Other
Shaped Paper	1.7341	0.9557	0.8253	1.2756	238,478	851,682	92,000,000	12,000,000,000	Wood & wood products	LT2: Other low technology
Aluminium Structures	1.5980	0.9442	0.5287	1.8358	231,280	512,517	110,000,000	10,000,000,000	Metals	LT2: Other low technology
Trailers	2.5090	0.9552	0.9216	1.5619	217,584	5,600,000	220,000,000	22,000,000,000	Transportation	MT2: Process industries
Synthetic Monofilament	1.5746	0.9543	0.8259	2.6078	170,427	352,356	20,000,000	1,200,000,000	Textiles/clothing	LT1: Fashion cluster
Aluminium Bars	1.4349	0.9482	0.5009	1.9552	157,624	448,232	200,000,000	17,000,000,000	Metals	Other primary products
Tractors	2.0854	0.9567	0.8545	1.4547	151,717	6,300,000	380,000,000	42,000,000,000	Transportation	MT3: Engineering industries

Source: Authors calculations, 2019

Table 5b: 'Frontier' Products Capable of Engendering Regional Trade (Using 2016 Export Basket) and ECOWAS Import Intensity Indices (cont'd)

Products	PCI	DISTANCE	OPGAIN	RCAm	EXPORT VALUE (US$)	ECOWAS EXPORTS (US$)	ECOWAS IMPORTS (US$)	WORLD IMPORTS (US$)	PRODUCT COMMUNITY	LALL CLASSIFICATION
Small Iron Containers	1.1318	0.9398	0.5197	1.1376	117,191	4,300,000	39,000,000	5,500,000,000	Metals	LT2: Other low technology
Used Rubber Tires	1.1431	0.9509	0.6491	3.1262	109,584	620,635	46,000,000	2,400,000,000	Plastics/rubbers	RB1: Agro/forest based products
Other Iron Bars	1.7205	0.9531	0.6454	1.7922	58,715	7,000,000	24,000,000	2,100,000,000	Metals	LT2: Other low technology
Polishes and Creams	1.2663	0.9482	0.7245	1.4897	56,424	369,555	18,000,000	2,000,000,000	Chemicals & allied industries	MT2: Process industries
Antifreeze	1.8290	0.9522	0.7853	1.0535	54,740	78,932	7,100,000	1,100,000,000	Chemicals & allied industries	MT2: Process industries
Asbestos Cement Articles	1.3486	0.9437	0.5341	1.2765	45,053	814,432	8,600,000	1,100,000,000	Stone/glass	RB2: Other resource based products
Opto-Electric Instrument Parts	2.5722	0.9555	1.0058	3.0803	31,762	63,331	53,000,000	2,800,000,000	Misscelaneous	HT2: Other high technology
Carbides	1.1737	0.9566	0.5160	1.1649	30,355	76,686	12,000,000	1,700,000,000	Chemicals & allied industries	RB2: Other resource based products
Plastic Wash Basins	1.7683	0.9528	0.6912	1.3626	28,435	73,276	29,000,000	3,400,000,000	Plastics/rubbers	LT2: Other low technology
Letter Stock	1.2886	0.9441	0.5159	1.0657	27,009	192,296	6,300,000	960,000,000	Wood & wood products	LT2: Other low technology
Cigarette Paper	1.1581	0.9497	0.6096	1.1739	24,191	51,423	14,000,000	2,000,000,000	Wood & wood products	LT2: Other low technology
Military Weapons	1.9048	0.9548	0.6487	26.1174	21,317	31,000,000	190,000,000	1,200,000,000	Misscelaneous	MT3: Engineering industries
Water and Gas Generators	1.7626	0.9523	0.7515	15.2975	19,016	335,492	80,000,000	840,000,000	Machinery/electrical	MT3: Engineering industries
Coated Metal Soldering Products	1.5997	0.9490	0.6352	3.1265	15,283	303,718	53,000,000	2,700,000,000	Metals	LT2: Other low technology
Metal Stoppers	1.5474	0.9513	0.6409	1.5513	11,792	1,900,000	56,000,000	5,800,000,000	Metals	LT2: Other low technology
Other Paints	1.4654	0.9468	0.6616	2.1975	11,013	243,171	10,000,000	740,000,000	Chemicals & allied industries	MT2: Process industries
Iron Sheet Piling	1.5507	0.9500	0.6599	1.2551	9,293	602,038	14,000,000	1,800,000,000	Metals	LT2: Other low technology
Friction Material	1.2546	0.9566	0.8370	1.1042	5,981	14,367	9,700,000	1,400,000,000	Stone/glass	RB2: Other resource based products
Chalk	1.2177	0.9538	0.7061	1.5857	5,696	175,729	1,500,000	150,000,000	Mineral products	Other primary products
Cellulose Fibers Paper	1.5471	0.9556	0.7632	2.0846	5,692	131,657	170,000,000	13,000,000,000	Wood & wood products	RB1: Agro/forest based products
Other Uncoated Paper	1.1921	0.9469	0.5442	1.2425	5,376	1,000,000	77,000,000	9,900,000,000	Wood & wood products	RB1: Agro/forest based products
Metal Signs	1.3090	0.9493	0.6309	1.6121	4,872	114,306	6,500,000	640,000,000	Metals	LT2: Other low technology
Granulated Slag	1.2569	0.9554	0.5094	1.5516	2,277	2,277	5,600,000	580,000,000	Mineral products	Other primary products
Cement Articles	2.0893	0.9512	0.7986	1.6356	1,600	250,559	79,000,000	7,700,000,000	Stone/glass	RB2: Other resource based products
Vegetable Fiber	1.6062	0.9495	0.6097	1.0623	1,002	12,976	2,600,000	390,000,000	Stone/glass	RB2: Other resource based products

Source: Authors calculations, 2019

4.0 Conclusion

The studies of Hausmann et al., (2007) and Hidalgo et al., (2007), and many others have posited that the nature of products constituting a country's export basket, reflecting the productive capabilities acquired over the years, matters a lot in any diversification drive. These productive capabilities for any country are captured by its ECIs. Hence, this study employs the concepts of ECI and PCI, Product Space, and RCA on trade data at the HS 4-digit classification level for 1240 products, for the period 2000 to 2016, to undertake comparative analyses between Ghana and selected countries (Nigeria, Singapore, and Malaysia) to address the question relating to why Ghana's export diversification drive has been extremely challenging. The study also examines sectors that have emerged from the products that Ghana has established comparative advantage and how the embedded productive knowledge capabilities have contributed to its structural transformation effort and export diversification drive. The study further identifies new products of strategic value that Ghana could easily deploy its acquired productive knowledge to promote future export diversification drive, particularly to take advantage of the ECOWAS market.

The results from the study suggest that Ghana's average level of sophistication (ECI) or collective know-how for the period 2000 to 2016, is not only low but also negative, like that of Nigeria. Besides, the evolution of its ECI has been quite uneven with no discernible trend. Indeed, the trajectories for the ECIs for the ECOWAS sub-region have generally been on the declining trend, suggesting that the productive capabilities of the sub-region could not offer much hope for significant structural transformation. On the contrary, countries in the East & Pacific regions, in general, demonstrate continuous improvement in the level of sophistication of their export baskets and for that matter the level of productive capabilities for them offer hope for more structural transformation. Specifically, for countries like Singapore and Malaysia, the average levels of sophistication have been high and quite impressive. Since low ECIs suggest low productive knowledge with limited capabilities to create enough complex network of interactions that can facilitate both backward and forward linkages, this can possibly lend credence to the reason why Ghana's export basket can be classified as less diversified and incapable of matching up to countries like Singapore and Malaysia.

Results from the descriptive analyses suggest that both Ghana and Nigeria have established RCA in sectors that focus on the production and export of vegetables, foodstuffs, and minerals. Due to the low levels of PCIs associated with most of these products, the prospects of scaling up value addition to propel industrialization, and facilitate the diversification of the export base of these economies at the extensive margin appear to be weak. Indeed, the sectors that emerged over the study period to reflect their respective acquired productive capabilities equally focused on the production of vegetables, foodstuff, and minerals. Ghana gained some RCA in the chemicals & allied sectors that could be exploited for further gains. This analysis may suggest that unless a paradigm change is implemented, the prospects of Ghana achieving any significant diversification of its export base is likely to be a mirage. And for Nigeria, the point may be made that its huge comparative advantage in the production and export of a product like crude oil is not translated into strength, notwithstanding its less ubiquitous nature. Since the value of PCI associated with crude oil is low, the strategic prospects can only be realised with judicious utilisation of the income flows from this natural resource to support the discovery of products with relatively high PCIs with strategic value to explore the value chain spectrum to ensure a more diversified economy. The narrative is different for Singapore and Malaysia. These countries established RCA in the machinery/electrical, chemicals and allied as well as the miscellaneous sectors, among others. With the level of sophistication and the complex network structures engendered by the production and export of these products, it is not surprising that these countries have not only exploited the value-chain spectrum to their advantage but have ensured broad-based diversified export based economies that foster shared growth.

To identify products that possessed the desirable characteristics Ghana may latch on to enhance its structural transformation agenda with prospects for a more diversified export base, the study employs a procedure designed by Hausmann and Jasmina (2015) by using a combination of the concepts of Proximity, Distance, and Opportunity gain within the context of product space network analyses. Based on these, the study identifies some ‘frontier’ products (that are currently within Ghana’s export basket for which the country does not have RCA), which Ghana can exploit to underpin its structural transformation and diversification drive. About 131 products

(later limited to 91 products based on an export value threshold of US$1,000 and above) are identified to be close to Ghana's current productive knowledge as reflected in its export basket for 2016. These products have the desirable characteristics that they have PCIs greater than one (suggesting relatively higher levels of sophistication with prospects for increasing the average level of sophistication of Ghana's export basket), minimal distance from the country's current export basket (feasible for exploitation at minimal effort), and relatively higher opportunity gains (prospects for opening new paths for diversification). Another important observation about these products is that not only do they possess the potential to help the country's structural transformation effort through the exploitation of the value addition spectrum in sectors that produce and export chemicals & allied products, plastic/rubber, stone/glass, and wood & wood products, but also offer the opportunity to mainstream technology in the industrialisation agenda of the country. Indeed, it is expected that the inclusivity to be engendered as a result of the process of multidimensional interactions involved in the production of such complex products would help in optimising the benefits to be derived along the value addition spectrum.

To assess how the identified products may be promoted within the ECOWAS sub-region, the study generates import intensity ratios like the RCAs for the imported products in the sub-region. The identified 'frontier' products are whittled down to 50 products after aligning them to the products that are intensively imported within the ECOWAS sub-region to guide any effort at exploiting the sub-regional competitive advantage.

Although these identified 'frontier' products may possess the potential to prop up the industrialisation agenda of the country, one must be guided by the conceptual framework underpinning this analysis that stresses the uncertainties associated with the process of discovering these new products. It is worth noting that the successful discovery of these products comes with some positive spillover effects beyond the firm which may have incurred the initial sunk cost for the venture. The benefits to be derived are susceptible to free riding. At the same time failure to achieve success from the investment becomes a private cost. The emerging uncertainties likely to be associated with such activities may discourage firms from venturing into such risky

yet potentially profitable inventions. This is where the lessons from Malaysia and Singapore come in handy, where there was a deliberate activist industrial policy by the governments by leveraging on fiscal policy to use domestic resources to enter into partnership arrangements with the private sectors in terms of research and development and the provision of the enabling economic, social, and political conditions as well as institutional infrastructure to enhance long-term financing and attract foreign direct investments that promote technology transfer and skills acquisition.

Specifically, the government through the Ministry of Finance can tinker with the fiscal regime (such as tax waivers and holidays) to encourage firms that are in the production of the identified frontier products as well as promoting R&D into these high PCI products. In addition, the government through the Ghana Investment Promotion Centre must pursue policies that encourage foreign direct investments in the real sectors of the economy that have the potential to boost technology and skills transfer in products with high PCIs, but not just in exploiting the exhaustible natural resources of the country. The government through the Ministry of Trade and Industry must promote sub-regional trade in the identified frontier products by stepping up efforts at reducing costs of doing business (especially transport and logistics, customs facilitation, among others) and deepening the recent paperless trade facilitation measures.

The key limitation of this study relates to the analytical technique used, which is largely descriptive, suggesting that the conclusions are suggestive, and one cannot infer causality. In addition, the analyses based on the economic complexity and product space concepts are largely tilted to the supply side of boosting export diversification, but this weakness was partially addressed in this study by the calculation of import intensity ratios for the ECOWAS sub-region to guide the future promotion of the identified frontier products. With the emerging significance of the services sector in the economy of Ghana, it will be useful for future research to consider a similar analysis of the export of service, when data becomes available.

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A TIME-VARYING GRANGER CAUSALITY APPROACH TO INFLATION-INSECURITY NEXUS IN NIGERIA

Chioma Peace Nwosu[1], Usenobong Akpan[2] and Ifunanya Maryjane Etudaiye[3]

Abstract

In this paper, we make some important contributions to the literature on insecurity and inflation nexus. First, our effort represents a major step in responding to the sparse empirical scrutiny of the subject for Nigeria. Secondly, our empirical strategy involves a time-varying Granger causality approach that allows for data-driven identification of the change points in the nexus - a major shift from other existing studies that do not account for such dynamism in the relationship. Overall, we found significant support that led us to at least three main conclusions. First, causal relationship between insecurity and inflation in Nigeria can change dramatically over any given sample period. Second, there is a unidirectional Granger causality running from insecurity to inflation in Nigeria, the starting episodes of which emerged late when considering year-on-year inflation and earlier when considering month-on-month inflation. Third, the hypothesis that inflation could be a trigger of insecurity in Nigeria failed our statistical test and hence rejected. The results suggest that tackling the question of insecurity is one of the ways to meaningfully address the persistence of Nigeria's inflationary pressures. In light of our findings, we suggest that authorities should deal decisively with the question of poverty and rising youth unemployment by expanding economic opportunities within the country. Furthermore, reforming the security architecture and strengthening the quality of institutions to decisively address all forms of insecurity should be a key policy priority.

Keywords: Granger causality, rolling, recursive and forward expanding window, time-varying, inflation, insecurity.
JEL Codes: C34, E31, I30

[123]Research Department, Central Bank of Nigeria.

1.0 Introduction and Related Literature

Nigeria has grappled with significant security challenges over the years, with diverse consequences, including substantial human and material costs. Indeed, the country's insecurity problem has expanded into different forms and intensity, ranging from terrorist activities to banditry, farmer-herder clashes, livestock rustling, kidnappings, armed robbery attacks, cult clashes, and heightened tensions from secessionist armed groups, amongst others. The 2023 Global Terrorism Index ranked Nigeria as the 8th most terrorist-afflicted country in the world in 2023, following Iraq (7th), Pakistan (6th), and Syria (5th), with Afghanistan at the top of the list (IEP, 2023)[4]. In addition to the challenge of insecurity, the country is also contending with persistent high inflation, which has crossed from single digits in 2015 to double digits, in the years after. Nigeria's inflation, which was 21.82 per cent in January 2023, accelerated to 26.72 per cent as of September 2023. Both challenges (inflation and insecurity) remained top priorities in public policy agenda in Nigeria, necessitating a continuous search for sustainable solutions.

Understanding the underlying causes of a phenomenon is essential for developing effective solutions. Against this backdrop, this paper examines the nexus between insecurity and inflation in Nigeria. Some of the critical questions that motivate this study are: Is Nigeria's persistent high inflation fuelled by heightened insecurity challenges? Is inflation equally a predictor of Nigeria's insecurity problem? Could both variables mutually reinforce each other?

Interestingly, the waves of insecurity and inflation dynamics around the world have generated significant research interest, both at the theoretical and empirical levels. From the theoretical perspective, the link between insecurity and inflation could be explained by the socio-economic grievances and relative deprivation theory due to the influential work of Gurr (1973). This theory suggests that insecurity may be stirred if there is a collective feeling of discontent or grievances by sense of economic and social deprivation. One way this could occur is the notion of frustration leading to aggressive behaviour, especially in a situation where there is a wide divergence between people's

[4] See list of the countries in Appendix

expected and actual material wellbeing (Ajide & Alimi, 2023; Yusuf & Mohd, 2022). Thus, it follows that people may become frustrated when there is persistent increase in the cost of living due to inflation, which makes their socio-economic well-being worse-off. Frustrated by hardship and a feeling that they are deprived of better economic well-being they justly deserve, the aggrieved could be induced to seek alternative audience of the authorities to their plight through violent crimes.

Ross(1993) and Piazza (2013) building on Gurr's framework, demonstrate how grievances, perceived or real, could perpetuate insecurity by providing an easy recruitment pool for terrorist organisations. However, Piazza (2013) presents another theoretical perspective that decreases in consumer prices could equally boost terrorist activities in at least two ways. The first is that declining consumer prices may force firms negatively impacted by lower profit margins to lay off workers or reduce their wages. Secondly, lower consumer prices would negatively impact small producers, such as family farmers, as income from their produce shrinks. Both consequences could result in economic resentments, grievances, and ultimately tolerance or support for terrorism. These theoretical foundations suggest that insecurity could be granger-caused by consumer prices. On the other hand, while there is scant theory linking higher consumer prices to insecurity, it is more plausible to hold the hypothesis that insecurity could likely disrupt supply chains and distribution networks, displace farming communities, lower production, and lead to a spike in food inflation as well as overall consumer price level.

From the empirical front, a large body of literature on the macroeconomic consequences of insecurity (e.g., Chuku *et al*., 2019; Fang *et al*., 2020; Otto, 2012; Mehmood, 2014; Yusuf & Mohd, 2022), suggests that insecurity hurts economic growth and investment. Ultimately, lower economic growth and investment would increase consumer prices. Nkemgha, *et al*. (2023), using the system GMM on a panel of Central African countries, found that apart from traditional sources (money supply, economic growth, and oil rent), insecurity is also one of the origins of inflation.

Evidence of causality from inflation to insecurity or vice versa has also been confirmed in several other studies (Ajide & Alimi, 2023; Tang, 2009; Ismail & Amjad, 2014;

Muhammad *et al*., 2011; Paldam, 1987; Shahbaz, 2013; Tang, 2011; Smith, 2014; Krieger & Meierrieks, 2011; Hazra & Cui, 2018). For instance, Smith (2014) shows that economic pressures from sudden and sharp increases in consumer food prices are significantly correlated with an increase in the probability of unrest in urban Africa. Empirical evidence from Tang (2009) equally suggests that the causality direction is from inflation and unemployment to crime in the case of Malaysia. Using a VECM Granger-causality approach, Shahbaz (2023) found a bidirectional causality between inflation and terrorism in Pakistan. However, for the same Pakistan, Malik & Zaman (2013) obtained unidirectional evidence of causality running from inflation to terrorism. Other evidence from Ajide & Alimi (2023) indicates that inflation volatility instead of inflation constitutes a significant predictor of terrorism in Africa. Ajide & Alimi's results seem to contradict previous evidence obtained by Bellemare (2011) that food price increases led to increased political unrest while food price volatility led to decrease in political unrest.

What could be deduced from the forgoing review is that: (1) there appears to be a relationship between insecurity and inflation; (2) the evidence is mixed, given the different methodologies employed and the influence of country-specific idiosyncrasies. Curiously, while insecurity is frequently referenced in public cycles as one of the causal factors of food inflation in Nigeria, and hence headline inflation, there is little or no empirical evidence to back up such claims. The role of inflation as one of the potential precipitants of insecurity in Nigeria has not also been given close empirical scrutiny. This paper is an attempt to fill this gap. Few papers that examine the problem in Nigeria (Chuku *et al*., 2019; Yusuf & Mohd, 2022) focused only on the growth and fiscal implications of insecurity, rather than inflation.

What is more? The existing studies on the causality between insecurity and inflation also ignored the time-varying dimensions of interactions between the two variables. Several studies have emerged to confirm that Granger causality could be evident or supported over one-time frame, but such evidence could be weak or absent when an alternative time frame is considered (see Thoma, 1994; Swanson, 1998; Arora & Shi, 2016; Phillips, *et al*, 2015a, 2015b; Psaradakis, *et al*, 2005; Shi *et al.*, 2020). The sometimes contradictory and confusing evidence does point to one general lesson:

causal relationships do change over time and links between insecurity and inflation can be quite sensitive to the sample period. This could be so, given that (1) it is possible that the influence of the variables on one another is not persistent; (2) government efforts in fighting both challenges could moderate the prominence of their influence over time; and (3) factors driving the two variables could be multivariate and hence their dominance as a major predictor at a given point in time may be time-varying. A logical inference suggests that opting for a testing framework that explicitly accommodates unidentified change points in causal relationship is more preferable to a conventional approach that either disregards or imposes a specific sub-sample choice on the data. Another main contribution in this paper, therefore, is accounting for the possibility of time-heterogeneity in causal relations between inflation and insecurity in Nigeria.

In terms of organization, this paper has three more sections. The next section provides a brief explanation of our research methodology and the nature of the data employed. Section three presents and discusses the empirical results while section four provides the conclusion and some insights for policy.

2.0 Methodology

2.1 The Time-Varying Granger Causality Approach

Granger (1969), in his seminal paper, proposed a notion of causality based on how well past values of a time series y_{1t} could predict future values of another variable y_{2t}. The widespread use of Granger causality is due to its straightforward identification through reduced-form VAR models, which are applicable to sets of potentially jointly determined variables. For instance, consider a bivariate VAR(p) model given as:

$$y_{1t} = \phi_{10} + \phi_{11}t + \sum_{k=1}^{p} \beta_{1k} y_{1t-k} + \sum_{k=1}^{p} \delta_{1k} y_{2t-k} + \mu_{1t} \quad (1)$$

$$y_{2t} = \phi_{20} + \phi_{21}t + \sum_{k=1}^{p} \beta_{2k} y_{1t-k} + \sum_{k=1}^{p} \delta_{2k} y_{2t-k} + \mu_{2t} \quad (2)$$

Where y_{1t} and y_{2t} represent the time series variables of interest, t is a time trend, k is the lag order, and the μ_{it} are the error terms. Given equations (1) and (2), variable y_{1t} is said to Granger cause y_{2t} if the past values of y_{1t} have predictive power for the current value of y_{2t}, conditional on the past returns of y_{2t}. Ultimately, the null hypotheses of no Granger causality, say from variable y_{1t} to variable y_{2t}, amounts to testing the joint significance of β_{2k} (k=1,…,p) by means of a Wald test, thus:

$$H_0 = \beta_{21} = \cdots = \beta_{2p} = 0 \quad (3)$$

That is, under the null, the estimated coefficients on the lagged values of y_{1t} are jointly zero. Failure to reject the null hypothesis is equivalent to failing to reject the hypothesis that y_{1t} does not Granger-cause y_{2t}.

Usually, the Granger causality VAR model framework requires that the variables are stationary. If the variables are non-stationary or co-integrated, the asymptotic theory from the traditional Granger causality approach would be invalid for hypothesis testing in the level VAR specification (Espoir *et al*., 2023). To directly account for integrated variables in the modelling framework, two influential studies, Toda & Yamamoto, (1995) and Dolado & Lütkepohl, (1996), recommended estimation of a Lag Augmented VAR (LA-VAR) model, such that equations (1) and (2) become:

$$y_{1t} = \phi_{10} + \phi_{11}t + \sum_{k=1}^{p+d} \beta_{1k} y_{1t-k} + \sum_{k=1}^{p+d} \delta_{1k} y_{2t-k} + \mu_{1t} \quad (4)$$

$$y_{2t} = \phi_{20} + \phi_{21}t + \sum_{k=1}^{p+d} \beta_{2k} y_{1t-k} + \sum_{k=1}^{p+d} \delta_{2k} y_{2t-k} + \mu_{2t} \quad (5)$$

Where the additional d lags in the VAR model augment the system for the possible maximum order of integration of the variables.

To allow for time variation in Granger causal orderings, Shi et al., (2020) proposed the use of three recursive testing algorithms for data-driven discovery of the change points in the causal relationships. These include the forward expanding window (FE) earlier considered by Thoma (1994) in the (non-augmented) original VAR model, the recursive rolling window (RO) based on Swanson (1998) and Arora & Shi (2016), and

a recursive evolving window (RE) algorithm described in Phillips et al, (2015a, 2015b), all of which utilize sub-sample tests of Granger causality within the LA-VAR framework described in equations (4) and (5).

Following Shi et al., (2020), consider a sample of $T + 1$ observations $\{y_0, y_1, \dots, y_T\}$. Let f_1 and f_2 be the (fractional) starting and ending points of the regression sub-samples and let the Wald test statistic calculated from this sub-sample by denoted by $W_{f_1 f_2}$. Furthermore, let $\tau_1 = [f_1 T]$, $\tau_2 = [f_2 T]$, where T denotes the total number of observations. Assume $\tau_0 = [f_0 T]$ denotes the minimum number of observations required to estimate the LA-VAR model.

The FE algorithm, which is a standard forward recursion, first computes the Wald test statistic for a minimum window length, $\tau_0 = [f_0 T] > 0$, and then expands the sample size sequentially by one extra observation per time until the final Wald test statistic is computed using the entire sample size. The FE considers the first data point ($\tau_1 = 1$) as the starting point of every sub-sample.

For the RO algorithm, a fixed window size (τ_0) is rolled through the sample, advancing one observation at a time, and a Wald Statistic is computed for each window. In other words, given the fixed regression window size equal to τ_0, the start point of the calibration moves from the first observation $\tau_1 = 1$ to $T - \tau_0 + 1$ and the endpoint $\tau_2 = \tau_1 + \tau_0 - 1$. Alternatively, the starting and end points of the regression could be written as $\tau_1 = \tau_2 - \tau_0 + 1$ and $\tau_2 = \{\tau_0, \dots, T\}$, respectively, where T is the last observation (see Shi, *et al.*, 2020).

The RE algorithm combines the procedure of both the FE and RO approaches, as a special case. Like the recursive rolling window (RO) algorithm, the endpoint of the regression window is still $\tau_2 = \{\tau_0, \dots, T\}$. However, rather than maintain a fixed distance, the regression procedure allows the distance between the starting point τ_1 and the endpoint τ_2 to vary and cover all possible values in the rolling window. Inference on Granger non-causality for each observation of interest is then based on a sequence of the backward sup Wald statistics, defined by Shi, *et al.*, (2020) as:

$$\mathcal{SW}_f(f_0) = \sup_{f_2=f, f_1\in[0, f_2-f_0]} \{\mathcal{W}_{f_1,f_2}\} \quad (6)$$

Where f is the fraction of the total sample, and f_1 and f_2 are the starting and ending points of the total sample, respectively.

For full sample analysis, testing the null hypothesis that a given variable does not Granger cause another at any time during the sample, against the alternative that there is Granger causality at some time, required a single Wald test statistic. The maximal FE, RO, and RE statistic is the largest element of the first row of the upper triangular matrix, the main diagonal matrix and the entire upper triangular matrix of test statistics, respectively. Beyond these summary measures for the full sample, the sequence of FE, RO and RE statistics can also be graphed and compared with the bootstrap percentiles derived by the methods described in Shi, *et al.,* (2020). Given these estimates, period(s) in which the Granger-causal relationship exists can be identified, where the test statistic exceeds the corresponding critical value.

Although Shi et al. (2020) have provided forward expanding window, rolling window and recursive evolving window algorithms to estimate the time-varying causality test, it has been proved that the recursive evolving window algorithm (which combines the features of the other two algorithms) provides the most reliable results with the highest power. For this reason, some authors have chosen to report only the RE window algorithm in their papers (e.g., Espoir et al., 2023). Hence, we would, in this paper, present the results for all three, but rely more on the sequence of the RE test statistics in adjudging the overall validity of the time-varying Granger causality results.

2.2 The Data and Preliminary Diagnostics

For robustness, we employ all the three components of the inflation series (food, core and headline) – each measured on the year-on-year and month-on-month basis, all drawn from the statistical database of National Bureau of Statistics (NBS). The series ranged from May 2011 to June 2023. The choice of May 2011, as the starting point, was guided by the availability of insecurity data. The data on insecurity were collected from the Nigeria Security Tracker (NST) database – a weekly updated databank of the

Council on Foreign Relations[5]. Two indicators of insecurity were available, namely, the number of deaths and the number of incidents. For our analysis, we used the number of incidents (in log form) to capture the influence of insecurity. In our view, incidents of insecurity, whether they result in deaths or not, can instil fear, amplify uncertainty, disrupt normal economic activities, constrain supply chains, and induce higher food and commodity prices in the near term. Overall, we believe the number of deaths from insecurity is a sub-set of number of incidents. The data captures all forms of incidence related to grievances (political, economic or social) channelled at the authorities or other affiliated entities as well as those arising from actions taken by the state in response to those security challenges.

Table 1 presents the summary statistics of the dataset. As displayed in the table, the average incident of insecurity over the sample period was over 17 cases, ranging from a minimum of 1 to a maximum of 52 cases per month (see also Figure 2). This underscored the depth of security challenges the country has contended with within the period. The average headline inflation (y-o-y), over the period, remained elevated in the double-digit region of 13.2 per cent, while food inflation stood at 14.7 per cent compared with 11.4 per cent average core inflation. The data reflects the dominant role of food inflation (y-o-y) as a key driver of year-on-year headline inflation over the period. However, on a month-on-month basis, headline inflation appears to be driven more by its core component, with a mean of 1.2 per cent compared with 0.9 per cent for food. These dynamics raise empirical research questions on the extent to which these developments could be attributed to the level of insecurity.

Table 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Insecurity	146	17.35	8.55	1.00	52.00
Headline Inflation (y-o-y)	146	13.19	4.06	7.70	22.79
Core Inflation (y-o-y)	146	11.43	3.32	4.08	20.06

[5] See https://www.cfr.org/nigeria/nigeria-security-tracker/p29483

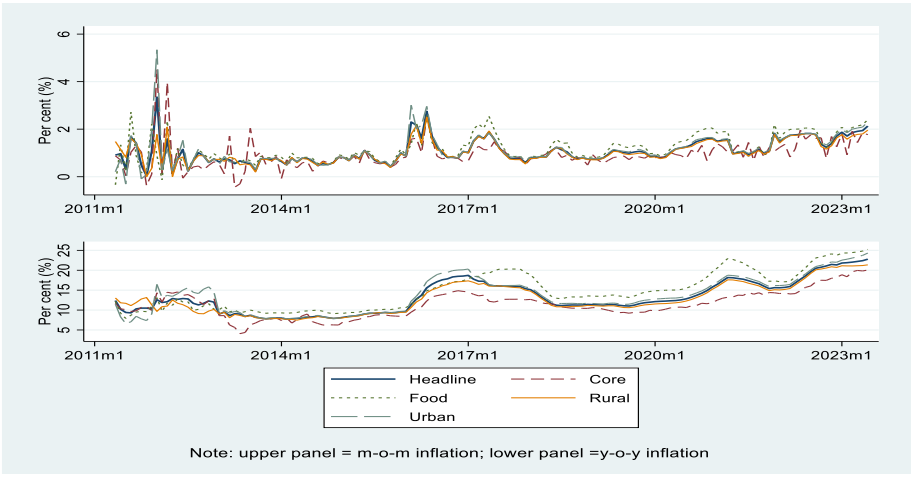
Food Inflation (y-o-y)	146	14.73	4.78	7.90	25.25
Headline Inflation (m-o-m)	146	1.07	0.51	0.04	3.35
Core Inflation (m-o-m)	146	0.93	0.62	-0.44	4.52
Food Inflation (m-o-m)	146	1.19	0.58	-0.34	2.72

Source: Authors' computation

Figures 1 and 2 display the dynamics of inflation series and insecurity indicators[6], respectively. The upper panel in Figure 1 shows the month-on-month inflation series while the lower panel captures the year-on-year measure. The inflation rate (y-o-y) tends to indicate a persistent uptick, rising from single digits in 2014-2015 to double digits in subsequent periods. However, the month-on-month inflation shows some form of stability, trending within single digits throughout the period of the analysis. In both cases, food inflation appears to lead the trend in most of the period. While it could be easier to attribute the noticeable spike in 2016-2017 to the 2016 economic recession in Nigeria and subsequent upward movements from 2020 to the COVID-19 pandemic crisis, the influence of insecurity on these dynamics is less evident to easily uncover by causal empiricism. For instance, judging from Figure 2, we observed that the incident of insecurity is highly volatile, with significant spikes noticeable in the early period and between 2014 to 2016. How these dynamics are influenced by inflation or contribute to inflation, remains the subject of our empirical evaluation.

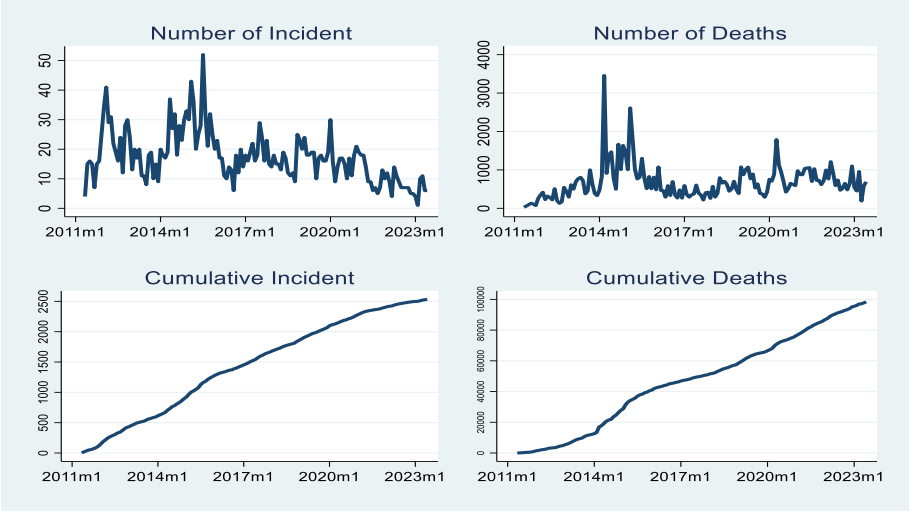
[6] Just for the sake of having a full picture of the stylised fact, we also plot the trend of number of deaths from insecurity along with the number of incidents. The later is the measure used in the analysis rather than deaths.

Figure 1: Dynamics of Inflation in Nigeria



Source: Authors' plot using data from NBS

Figure 2: Nigeria's Insecurity Indicators



Source: Authors' plot using data from NST.

We conclude the preliminary diagnostics of the data by performing a simple correlation analysis and the results are displayed in Table 2. Our interest lies in the first column, which shows the correlation between insecurity and the various components of inflation. The result returns overwhelming evidence of a correlation between insecurity and inflation in Nigeria. The correlation coefficients were all significant at a 5 per cent level. Notably, food inflation (for both y-o-y and m-o-m measures) has the highest correlation coefficient with insecurity, relative to core inflation. This appears to lend support to the disruptive influence of insecurity on farming activities in Nigeria. The fact that core inflation also bears a significant correlation with insecurity suggests that the influence of insecurity on inflation in Nigeria could be broader than what has been casually inferred by policymakers. Noting, however, that correlation does not reveal direction of the relationship, it remains unclear if there is a unidirectional or bidirectional relations between both variables. We deal with this in the next section of the paper.

Table 2: Pairwise Correlations Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Insecurity	1.000						
(2) Headline Inflation (y-o-y)	0.514*	1.000					
	(0.000)						
(3) Core Inflation (y-o-y)	0.445*	0.928*	1.000				
	(0.000)	(0.000)					
(4) Food Inflation (y-o-y)	0.507*	0.947*	0.832*	1.000			
	(0.000)	(0.000)	(0.000)				
(5) Headline Inflation (m-o-m)	0.330*	0.575*	0.549*	0.544*	1.000		
	(0.000)	(0.000)	(0.000)	(0.000)			
(6) Core Inflation (m-o-m)	0.191*	0.409*	0.445*	0.401*	0.737*	1.000	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
(7) Food Inflation (m-o-m)	0.330*	0.552*	0.492*	0.562*	0.817*	0.528*	1.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	

** Shows significance at p<0.05; the values enclosed in the bracket behind each of the correlation coefficients are the p-values*

Source: Authors' computation

3.0 Empirical Findings

3.1 Unit Root Test

While the lag-augmented VAR (LA-VAR) testing technique does not require pre-filtering the data series by de-trending or taking differences, it does need information about the maximum possible order of integration (see Shi *et al.*, 2020). Against this backdrop, we perform the Augmented Dickey-Fuller (ADF) tests for the series (Dickey and Fuller, 1979), with a constant and a linear time trend assumption in the regression equation. Furthermore, we apply the unit root test procedures of Perron and Vogelsang (1992) and Clemente, Montanes, and Reyes (1998) to account for potential structural breaks in the data series; each of these tests searches for unknown structural breaks with either additive outliers (AO) or innovational outliers (IO). While the Perron-Vogelsang test allows for one structural break, the Clemente *et al.* (1998) test allows for two breaks. The null hypothesis, for both tests, is that there is a unit root, against the alternative of stationarity series.

The test results are displayed in Tables 3a and b. All data series were found to be ***1***(1) using the ADF test procedure, which assumes no structural breaks, aside from insecurity that was ***1***(0). Accounting for one or two unknown structural breaks with additive or innovative outliers – the AO and IO tests of Perron and Vogelsang (1992) and Clemente *et al*. (1998) for the year-on-year inflation data did not suggest the presence of structural breaks in the data set, except for core inflation in the case of IO test. However, the month-on-month inflation series were all found to be ***I*** (1) series using the Perron and Vogelsang (1992) one structural break or Clemente *et al*. (1998) two structural breaks, except for headline inflation for AO's two structural breaks. We conclude, therefore, that for the year-on-year series, the ADF test of no structural breaks is more reliable. Overall, the results imply that the maximum order of integration for the series is ***I*** (1). Consequently, our analysis proceeds in the context of an LA-VAR model where $d = \mathbf{1}$ in our equations (4) and (5).

Table 3a: Unit Root Tests (Using y-o-y inflation)

	ADF	**Perron & Vogelsang (1992)**		**Clemente *et al* (1998)**	
	Const. & trend	AO	IO	AO	IO
Levels					
Headline	-1.112	-2.342	-1.972	-3.06	-4.114
Core	-1.549	-2.053	-1.621	-2.079	-1.576
Food	-1.795	-1.612	-2.183	-2.878	-3.291
Insecurity	-6.608***	-0.355	-0.356	-0.469	-0.576
First Difference					
Headline	-8.810***	-2.139	-2.491	-1.267	-3.476
Core	-14.070***	-3.088	-4.576***	-3.829	-6.036***
Food	-10.939***	-2.614	-2.698	-2.485	-2.552
Insecurity	-16.986***	-1.650	-2.585	-2.794	-2.829
5% critical value	**-3.444**	**-3.560**	**-4.270**	**-5.490**	**-5.490**

Note: **** shows significance at p<0.05.*

Table 3b: Unit Root Tests (Using m-o-m inflation)

	ADF	**Perron & Vogelsang (1992)**		**Clemente *et al* (1998)**	
	Const. & trend	AO	IO	AO	IO
Levels					
Headline	-1.112	-0.444	-1.458	-0.166	-0.634
Core	-1.549	-2.640	-1.128	-0.206	-2.533
Food	-1.795	-1.119	-1.925	-2.476	-3.638
Insecurity	-6.608***	-0.355	-0.356	-0.469	-0.576
First Difference					
Headline	-8.810***	-10.204***	-7.282***	-3.379	-8.573***
Core	-14.070***	-8.032***	-4.889***	-6.267***	-9.074***
Food	-10.939***	-6.934***	-7.899***	-5.932***	-7.622***
Insecurity	-16.986***	-1.650	-2.585	-2.794	-2.829
5% critical value	**-3.444**	**-3.560**	**-4.270**	**-5.490**	**-5.490**

Note: **** shows significance at p<0.05*

3.2 Granger Causality Results Between Inflation and Insecurity

To investigate the causal relationship between inflation and insecurity in Nigeria, we set the maximum number of lags (p) to 12 as our data are monthly series. In all cases, the optimal lag order of the VAR model is then selected using Schwarz's Bayesian information criterion (SBIC), reputed for providing more parsimonious lag-order selection. In performing the time-varying analysis under the three algorithms (the forward expanding window, rolling window and recursive evolving window), we set the initial estimation window size to 72 observations (6 years), and controlled the size of the test over one year. We assume the presence of a linear trend in the VAR model, which is plausible, particularly for our inflation series. The decision rule in each case is by comparing the estimated FE, RO, and RE critical values with the 90th, 95th and 99th percentiles of the empirical distributions of the bootstrap statistics. To allow for robustness, we consider the heteroskedasticity consistent versions of the tests (as in Shi et al., 2020)

Letting ⇒ indicates the null hypothesis that the first variable does not Granger-cause the second one, we proceed, firstly, with the results using the year-on-year inflation series. Table 4 presents the results for the full sample while Figures 3 to 5 display the time-varying Granger causality test results between insecurity and headline, core and food inflation, respectively. From Table 4, our results for the full sample suggest the presence of unidirectional causality from insecurity to inflation in Nigeria. In specific terms, both the rolling window and recursive evolving window algorithms show robust evidence of causality running from insecurity to headline and core inflation. Evidence of insecurity Granger-causing food inflation was only confirmed by the recursive window procedure, but only at the 5 per cent level. The forward-expanding window procedure fails to confirm any causality between the two variables of interest[7]. Results from all three algorithms did not establish any evidence of Granger causality from inflation to insecurity. Relying on the RO and especially the RE test statistics, we can

[7] The fact that the FE window fails to pick up the causal channels confirms a well-known problem with the FE algorithm: namely, that it is not sensitive to changes late in the sample period.

infer that there is a unidirectional relationship from incidents of insecurity to year-on-year inflationary pressures in Nigeria (particularly headline and core).

Table 4: Granger Causality between Inflation (y-o-y) and Insecurity: Full Sample

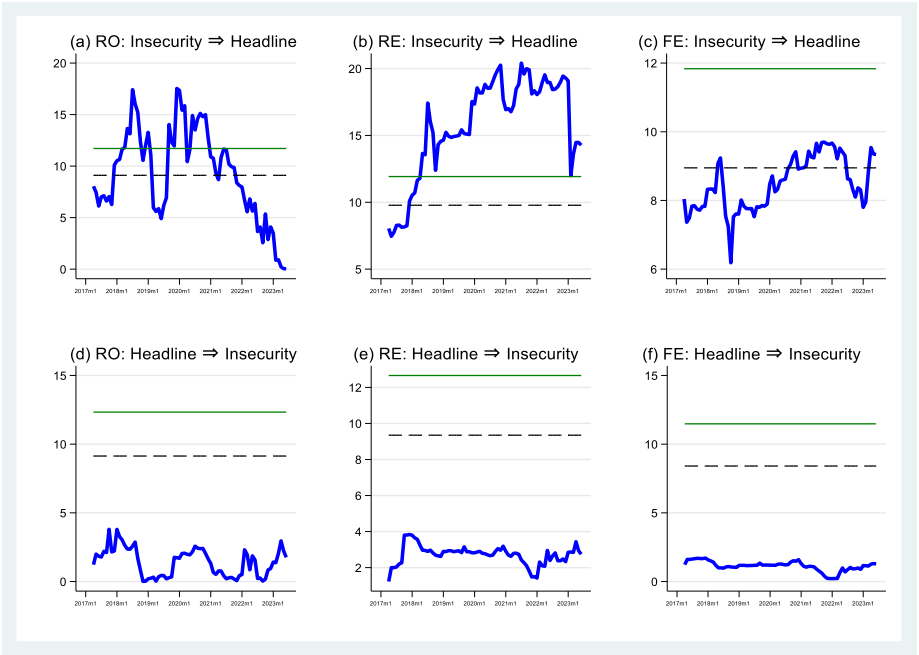
Direction of Causality	Max Wald FE	Max Wald RO	Max Wald RE
Insecurity ⇒ headline inflation	9.701 (11.836) [19.273]	17.539** (11.712) [17.968]	20.412*** (11.925) [19.273]
Insecurity ⇒ core inflation	5.344 (9.642) [17.434]	22.154*** (10.878) [17.914]	24.634*** (11.218) [17.914]
Insecurity ⇒ food inflation	10.790 (11.768) [19.237]	9.833 (12.086) [19.021]	16.690** (12.588) [19.273]
Headline inflation ⇒ Insecurity	1.713 (11.482) [18.283]	3.803 (12.335) [18.731]	3.838 (12.662) [19.258]
Core inflation ⇒ Insecurity	0.614 (11.154) [14.716]	5.168 (11.832) [14.716]	5.794 (11.844) [14.905]
Food inflation ⇒ Insecurity	2.716 (7.459) [17.280]	4.870 (10.665) [17.280]	4.870 (10.896) [17.280]

Note: *Note: The 95th and 99th percentiles of the empirical distributions of the bootstrap statistics are in parenthesis () and brackets [], respectively; ** and *** denote significance at 5% and 1%, respectively. FE=Forward Expanding Window; RO=Rolling Window; and RE = Recursive Evolving Window. ⇒ indicates the null hypothesis that the first variable does not Granger-cause the second one. Granger-causal relationship is identified, where the test statistic exceeds the corresponding critical value.*

Source: Authors' estimation

Moving ahead, to uncover the time-varying dimensions of the relationship, we plot the sequence of the FE, RO and RE test statistics and the corresponding 90th and 95th percentiles of the bootstrap statistics, in Figures 3 to 5. Starting with Figure 3, which shows the results for headline inflation (y-o-y) and insecurity, the plots support the conclusion that the relationship between both variables could be extremely dynamic over time and highlight the danger of using Wald tests of Granger causality indiscriminately over the full sample. Indeed, estimations using the RO and RE windows indicate that during most of the study period, there was evidence of Granger causality from headline inflation to insecurity. However, as shown, using the RO approach, strong evidence of Granger causality could only be detected between 2018M1 to 2019M2 and from 2019M9 to 2021M2. Using the most reliable RE window, the evidence of Granger causality was apparent from 2018M1 and throughout the rest of the period, suggesting the persistence of insecurity as one of the chief drivers of inflationary pressures in Nigeria. Correspondingly, the graphs in the lower panel of Figure 3 show no reverse Granger causality from insecurity to headline inflation.

Figure 3: Time-Varying Granger Causality Between Insecurity and Headline Inflation (y-o-y)

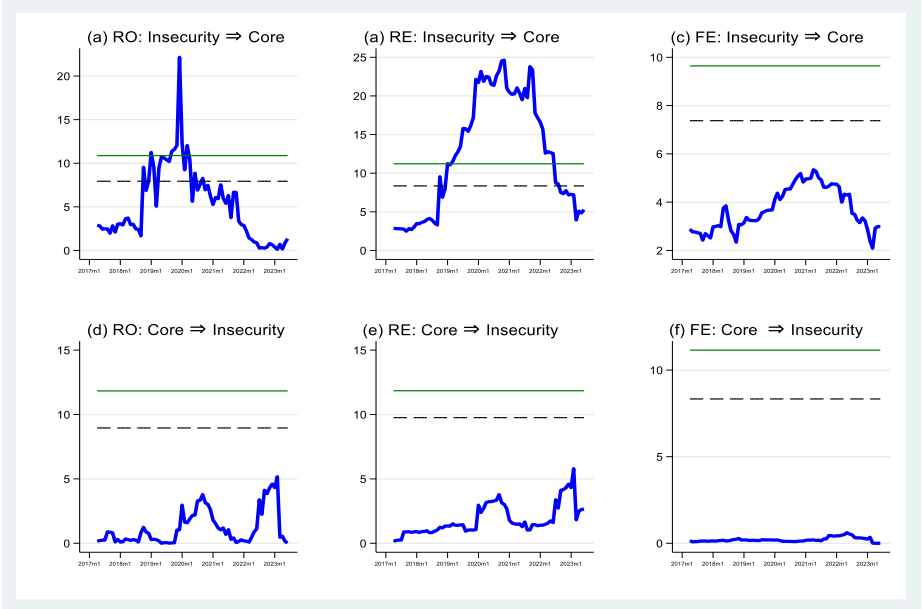


Notes: *The upper green horizontal line and the lower black dotted line represent 90th and 95th percentiles of the empirical distributions of the bootstrapped test statistics, respectively. The blue line graphs show the sequence of RO, RE and FE robust statistics (from 199 replications). ⇒ indicates the null hypothesis that the first variable does not Granger-cause the second one. Granger-causal relationship is identified, where the test statistic exceeds the corresponding critical value.*
Source: Authors' estimation

Further evidence from Figures 4 and 5 suggests that the influence of insecurity on Nigeria's inflationary problem could be more on core than food inflation. For instance, in Figure 4, we found evidence of unidirectional Granger causality from insecurity to inflation dating between 2019M5 to 2019M12 using the RO window and between 2019M1 to 2022M9 under the more reliable RE algorithm. As before, the FE procedure fails to confirm evidence of causality. Turning to Figure 5, an episode of

unidirectional Granger causality from insecurity to food inflation is detected by the RE algorithm from 2020M1 and the influence lasts through the end of the sub-sample. Again, we reject the hypothesis that food inflation Granger causes insecurity. This suggest that incidents of insecurity contribute to supply chain disruptions, affecting the transportation and distribution network for goods and services across the country. A classic example of this is the sit-at-home order on Mondays in south-eastern Nigeria, preventing smooth economic activities as well as the movement of goods and services, to and from other parts of the country. In the Northern region, the activities of banditry and insurgents, are also having similar deliberating influence on economic activities and supply chain, and hence on consumer prices.

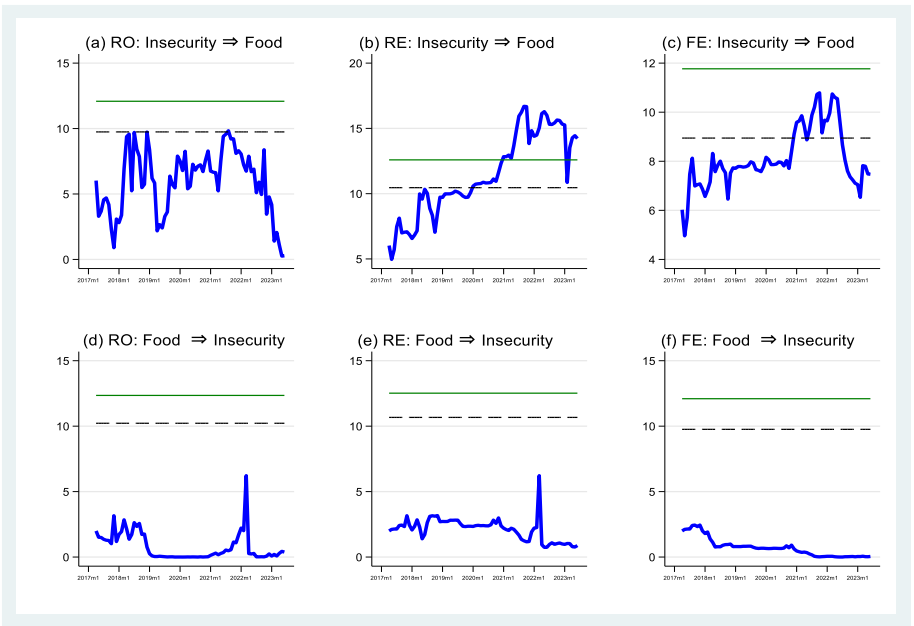
Figure 4: Time-Varying Granger Causality Between Insecurity and Core Inflation (y-o-y)



Note: *The upper green horizontal line and the lower black dotted line represent 90th and 95th percentiles of the empirical distributions of the bootstrapped test statistics, respectively. The blue line graphs show the sequence of RO, RE and FE robust statistics (from 199 replications). ⇒ indicates the null hypothesis that*

the first variable does not Granger-cause the second one. Granger-causal relationship is identified, where the test statistic exceeds the corresponding critical value.
Source: Authors' estimation

Figure 5: Time-Varying Granger Causality Between Insecurity and Food Inflation (y-o-y)



Note: *The upper green horizontal line and the lower black dotted line represent 90th and 95th percentiles of the empirical distributions of the bootstrapped test statistics, respectively. The blue line graphs show the sequence of RO, RE and FE robust statistics (from 199 replications). ⇒ indicates the null hypothesis that the first variable does not Granger-cause the second one. Granger-causal relationship is identified, where the test statistic exceeds the corresponding critical value.*
Source: Authors' estimation

Overall, our findings are broadly consistent with previous evidence provided by Nkemgha, *et al.* (2023) for some Central African countries that insecurity is one of the origins of inflation. Our result, however, differs from several other empirical studies (e.g. Tang, 2009; Malik & Zaman, 2013; Smith, 2014; Piazza, 2013; Ajide & Alimi,

2023; Yusuf & Mohd) that attribute insecurity to economic grievances and frustration induced by inflationary pressures. While not dismissing the possibility of the economic deprivation and frustration thesis contributing to insecurity elsewhere, we have no statistical confidence or support, going by our results, to believe that such is responsible for Nigeria's security challenges. This is quite instructive as it tends to portray the peculiarity of the Nigerian situation. Indeed, the political economy of insecurity in Nigeria appears to suggest (to a large extent) a different direction as per the origin and nature of the crisis. Specifically, some conflict-related papers in Nigeria have documented that insecurity in the country is triggered more by religious and political sentiments, and for reasons of ethnic fragmentations (see Chuku, *et al.*,2019), which have very little to do with inflationary pressures. One reasonable argument is the elite-motivated[8] nature of insecurity in Nigeria, originating from the contention for oil rents, the struggle for fiscal federalism and restructuring, and an increased perception of marginalisation in the political structure of Nigeria, which primarily contributed to the emergence of armed conflicts and militia groups in the southern part of Nigeria. Religious extremism and extra-judicial killings by state actors have also been fingered as the root cause of insecurity in the northern part of the country (see Amnesty International, 2016). That unemployment could be a major factor in crime has been confirmed in several other studies (e.g., Tang, 2011). Consequently, higher population growth and limited economic opportunities, resulting in high youth unemployment, may have equally contributed to making banditry a booming industry in Nigeria, amid weak institutional capacity to contend with the menace. For instance, according to Augusto & co (2022), Nigeria's insecurity debacle has not only coincided with rising poverty levels of about 83 million people as of April 2022 (an 18% increase from 70 million people in 2016) but it has been exacerbated by worsening unemployment rate (estimated at 33% as at 2020Q4).

In sum, although the influence of these factors was not the subject of the present paper but key issues for future empirical searchlight, our major take are the following: (1)

8 In fact, Chuku, et al., (2019) maintain that insecurity in Nigeria bears imprints of elite sponsorship, as it is difficult for perpetrators of insecurity, especially armed militia and terrorist groups, who often appeared as poor and uneducated rural dwellers, to mobilize sufficient resources and capacity to launce and sustained large-scale campaigns against the state for a prolong period.

inflation is not a driver of Nigeria's insecurity escalation, and (2) Insecurity has a time-varying influence on inflation in Nigeria. Taken together, we infer that there is a unidirectional Granger causality from insecurity to inflation in Nigeria, but the influence is time-varying.

3.3 Robustness Check

To evaluate the robustness of our results, we conduct some sensitivity checks by replacing the year-on-year inflation rates with month-on-month inflation series and recalibrating the results. The results of this exercise are shown in the appendix (Table A2 and Figures A1 to A3). Overall, our analysis returns consistent outcomes that there is a unidirectional Granger causality running from insecurity to inflation in Nigeria. The difference, though, is that the influence is now more pronounced, and showed up strongly too on all the components of inflation, judging from the RO and RE window algorithms (see Table A2). Evidence from Figure A1 indicates that insecurity exerts a dominant and persistent influence on headline inflation throughout the sample window, using the RE procedure. However, using the RO window, such influence was only visible between 2017M3 to 2019M1, and between 2022M1 to 2023M1. For core and food inflation, we also observe, at 5% level of significance, the persistent influence of insecurity on the two components throughout the sample estimation window, using the RE algorithm. However, using the RO window, we can only dictate the influence of insecurity on month-on-month food inflation in 2018 and thereafter between 2022M2 to 2023M1, mirroring the headline inflation episodes using the same recursive algorithm.

It does suggest that the influence of insecurity on inflationary pressures in Nigeria is felt more month-on-month than year-on-year because the immediate impacts of insecurity, such as supply chain disruptions, sudden spikes in transportation costs, and abrupt shortages of goods, tend to cause rapid price increases. These short-term shocks quickly affect the cost of living and consumer prices, leading to noticeable inflationary pressures within a given month. Over a longer period, such as a year, the economy may have time to adjust to these disruptions, and other economic factors may mitigate the impact of insecurity. Additionally, the persistence of insecurity can cause

businesses and consumers to adapt their behaviours, reducing the volatility of price changes and spreading the economic impact over a more extended period.

4.0 Conclusion

4.1 Summary

In this paper, we make some important contributions to the literature on insecurity and inflation nexus. First, our effort represents a major step in responding to the sparse empirical scrutiny of the subject for Nigeria. Secondly, our empirical strategy involves a time-varying Granger causality approach that allows for data-driven identification of the change points in the nexus. This represents a major improvement over other existing studies that do not account for such dynamism in the relationship.

Overall, we found significant support that led us to, at least, three main conclusions. First, the causal relationship between insecurity and inflation in Nigeria can change dramatically over any given sample period, and hence arbitrarily choosing the sample period over which to conduct causality test may lead to misleading inference. Second, there is a unidirectional Granger causality running from insecurity to inflation in Nigeria, the starting episodes of which emerged late when considering year-on-year inflation and earlier when considering month-on-month inflation. Third, the hypothesis that inflation could be a trigger of insecurity in Nigeria failed our statistical test and was hence rejected. We believe this to be a clear indication that Nigeria's insecurity challenges are well beyond the subject of consumer prices, but could be influenced more by other factors like political and ethic fragmentations, as well as limited economic opportunities that create a large pool of unemployed youths amid weak institutional capacity that enables the problem to fester for a prolonged period. The results suggest that tackling the question of insecurity is one of the ways to address the persistence of high inflation in Nigeria.

4.2 Policy Recommendations

In light of the above, we suggest that policy should be directed at tackling the menace of insecurity. One practical way in achieving this is to deal decisively with the question of poverty and rising youth unemployment by expanding economic opportunities within the country. Furthermore, reforming the security architecture and strengthening

the quality of institutions to decisively deal with all shades of insecurity are equally important.

Appendix

Table A1: Top 10 Countries Impacted by Terrorism in 2023

Source: Global Terrorism Index, 2023.

Country	Rank	Score
Afghanistan	1	8.822
Burkina Faso	2	8.564
Somalia	3	8.463
Mali	4	8.412
Syria	5	8.161
Pakistan	6	8.160
Iraq	7	8.139
Nigeria	8	8.065
Myanmar (Burma)	9	7.977
Niger	10	7.616

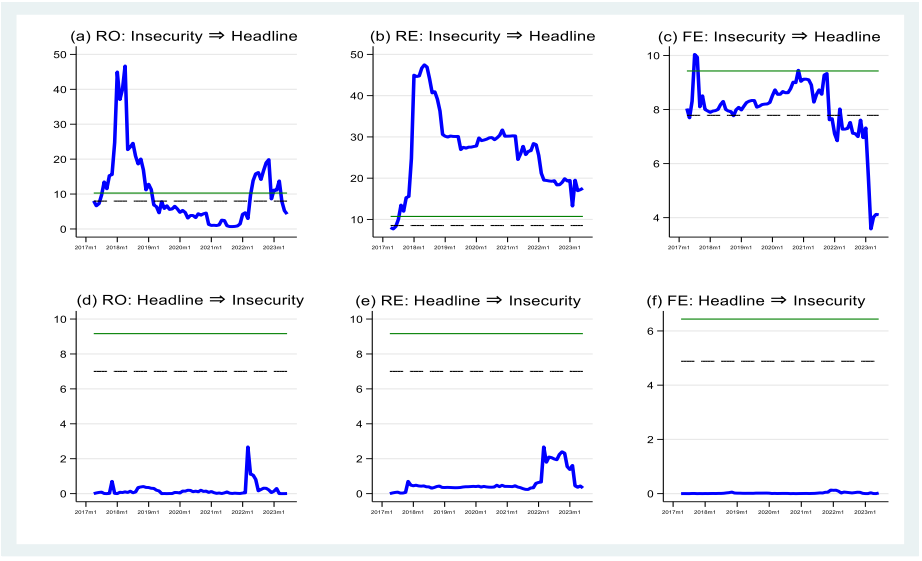
Table A2: Granger Causality between Inflation (m-o-m) and Insecurity: Full Sample

Direction of Causality	Max Wald FE	Max Wald RO	Max Wald RE
Insecurity ⇒ headline inflation	10.040** (9.427) [15.952]	46.684*** (10.286) [14.524]	47.473*** (10.733) [15.952]
Insecurity ⇒ core inflation	11.933** (11.863) [14.686]	17.946*** (12.975) [22.941]	21.541** (13.183) [23.656]
Insecurity ⇒ food inflation	1.217 (10.457) [17.124]	28.965*** (10.791) [17.124]	28.965*** (11.211) [17.124]

Headline inflation ⇒ Insecurity	0.132 (6.439) [8.297]	2.677 (9.165) [12.903]	2.677 (9.165) [12.930]
Core inflation ⇒ Insecurity	1.776 (7.679) [13.315]	6.832 (11.045) [18.709]	8.758 (11.363) [18.976]
Food inflation ⇒ Insecurity	2.446 (12.099) [17.522]	6.219 (12.350) [22.241]	6.219 (12.522) [22.584]

Note: *The 95th and 99th percentiles of the empirical distributions of the bootstrap statistics are in parenthesis () and brackets [], respectively; ** and *** denote significance at 5% and 1%, respectively. FE=Forward Expanding Window; RO=Rolling Window; and RE = Recursive Evolving Window. ⇒ indicates the null hypothesis that the first variable does not Granger-cause the second one. Granger-causal relationship is identified, where the test statistic exceeds the corresponding critical value.*

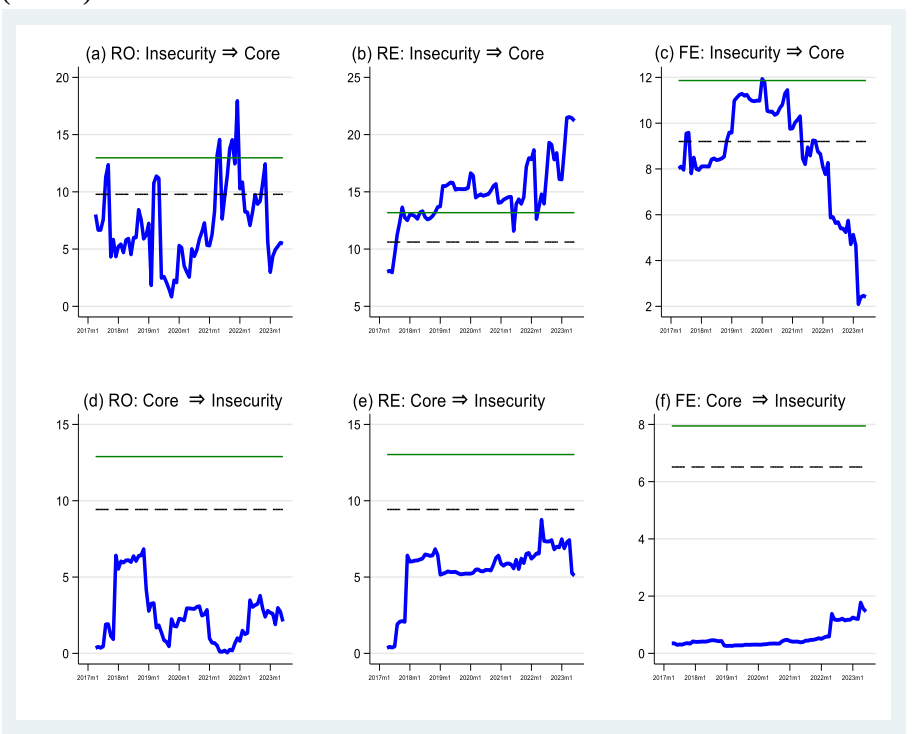
Figure A1: Time-Varying Granger Causality Between Insecurity and Headline Inflation (m-o-m)



Note: *The upper green horizontal line and the lower black dotted line represent 90th and 95th percentiles of the empirical distributions of the bootstrapped test statistics, respectively. The blue line graphs show the*

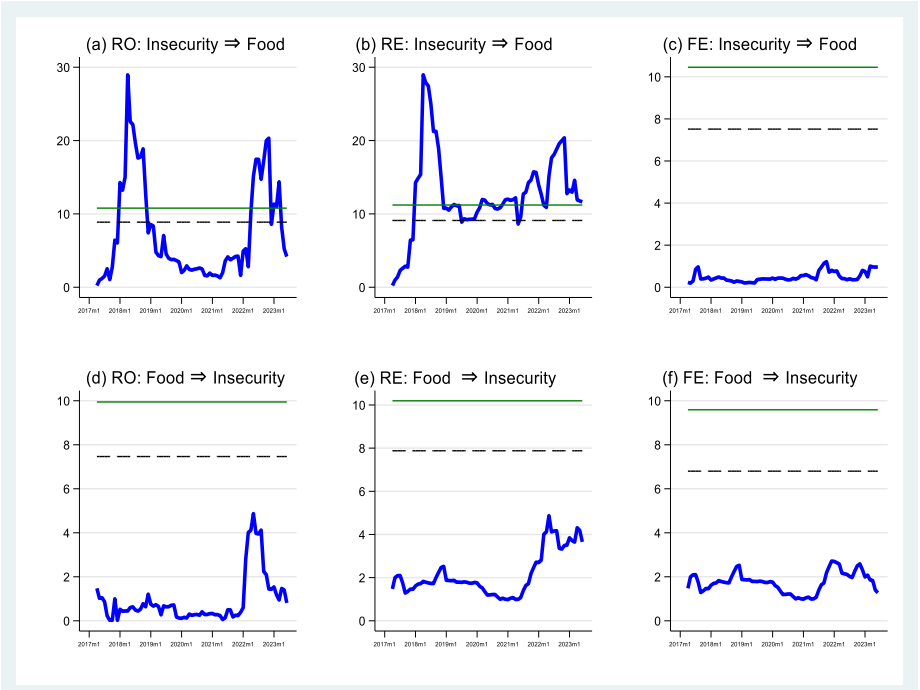
sequence of RO, RE and FE robust statistics (from 199 replications). ⇒ indicates the null hypothesis that the first variable does not Granger-cause the second one. Granger-causal relationship is identified, where the test statistic exceeds the corresponding critical value.

Figure A2: Time-Varying Granger Causality Between Insecurity and Core Inflation (m-o-m)



Note: *The upper green horizontal line and the lower black dotted line represent 90th and 95th percentiles of the empirical distributions of the bootstrapped test statistics, respectively. The blue line graphs show the sequence of RO, RE and FE robust statistics (from 199 replications). ⇒ indicates the null hypothesis that the first variable does not Granger-cause the second one. Granger-causal relationship is identified, where the test statistic exceeds the corresponding critical value.*

Figure A3: Time-Varying Granger Causality Between Insecurity and Food Inflation (m-o-m)



Note: *The upper green horizontal line and the lower black dotted line represent 90th and 95th percentiles of the empirical distributions of the bootstrapped test statistics, respectively. The blue line graphs show the sequence of RO, RE and FE robust statistics (from 199 replications). ⇒ indicates the null hypothesis that the first variable does not Granger-cause the second one. Granger-causal relationship is identified, where the test statistic exceeds the corresponding critical value.*

Source: Authors' estimation

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EXTERNAL RESERVES AND THE ELASTICITY OF SUBSTITUTION BETWEEN DOMESTIC AND FOREIGN INVESTMENTS IN NIGERIA

Ogiji Patricks[1], Chidi Ihediwa[2] and Umeokwobi Richard[3]

Abstract

Understanding the dynamics between different investment types and their impact on external reserves is crucial for Nigeria's economic stability and growth. The study assessed the impact of different types of investment flows on Nigeria's external reserve movements, focusing on the elasticity of substitution between domestic and foreign investments from January 2008 to December 2023. Using data from the CBN Statistical Bulletins and applying the ARDL Bounds Test, we explore the relationships between external reserves, domestic investment (gross capital formation), and foreign investments (foreign portfolio and direct investments). The results reveal that foreign portfolio investment positively and significantly impacts long-run external reserve accumulation, while foreign direct investment has a negative and insignificant effect. The domestic investment, proxied by gross capital formation, has a negative yet significant coefficient. The elasticity of substitution analysis indicates that substituting domestic investment for foreign portfolio investment leads to an inelastic external reserve position, while substituting foreign direct investment for domestic investment shows a more elastic and preferable outcome.

Keywords: ARDL, External Reserve, Domestic Investment, Foreign Investment
JEL Classification: C50, F21, F33,

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[123] Central Bank of Nigeria

1.0 Introduction

For most emerging markets and developing economies (EMDEs), a growing body of evidence and economic theory suggest that the availability of a diverse set of alternative sources of foreign exchange earnings is important both for external reserve accretion, macroeconomic stability, and economic growth. One way in which some economies have attempted to stabilize their external reserves is to encourage more investment domestically as the main component of output growth and to dampen the pressure on the external reserves. The over-dependence on imports by most EMDEs has continued to put pressure on their external reserves. The situation requires re-examination with calls over time on the urgent need to encourage both domestic direct investments (DDI, made up of public investment and private investment) and domestic portfolio investments (DPI, made up of stocks, bonds, and other financial assets) as a way of building external reserves. While DDI would boost domestic production and reduce imports with the possibility of improving export earnings in the future, the size of DPI could cushion the vagaries of capital flight from the domestic economy with a possibility for the preservation of external reserves. This also depends on whether the policy measures in place in the domestic economy are sufficient to encourage financial disinvestment overseas by domestic residents, that is a drop in capital outflow. This would partially offset any sudden drop in foreign portfolio inflows during periods of crisis. Several studies emphasize the role of domestic investment in stabilizing external reserves. For instance, Razin and Collins (1999) argue that increased domestic investment can reduce dependency on foreign capital, thus stabilizing reserves. Similarly, Kim and Yang (2009) suggest that by boosting domestic production, countries can reduce their reliance on imports, thereby preserving external reserves.

Foreign investments, particularly portfolio flows, are large and often distortionary as they have tendency to drop during periods of global crises. They could trigger a crisis because of their volatile nature and depending on the level of the country's exposure to external shocks. Foreign direct investments (FDI), on the other hand, are hardly forthcoming because of cyclical fluctuations (trade flows and terms-of-trade fluctuations), structural factors (the dearth of infrastructure and other legacy issues), labour laws, indigenization policies, and the legislation around taxes and ease of doing

business in most EMDEs. Foreign portfolio investments (FPI) have thus far remained a very significant and foremost source of capital flows to most EMDEs.

Nigeria continues to remain a major beneficiary of foreign portfolio flows because of favourable yields. Nevertheless, they are very volatile and should be handled with caution. Studies like those by Froot, O'Connell, and Seasholes (2001) highlight that EMDEs, including Nigeria, attract substantial FPI due to high yields and potentially higher returns compared to developed markets.

Our motivation is consistent with the opinion that high foreign investment inflows are consistent with higher reserve accretion and stability in the naira exchange rate. Over time, there have been deliberate policy measures to encourage foreign portfolio inflows. While these inflows, always generate positives impacts on the stock of international reserves, there is always, the palpable fear of flow reversals or the possibility of sudden stop as was witnessed in the aftermath of global financial crisis of 2007/2008 and recently, in the aftermath of the outbreak of the global COVID-19 pandemic when the entire world economy was shut down. BusinessDay (June 25, 2020), citing data on stock market transactions in May 2020, reported that domestic investors accounted for 70 percent of market transactions on the Nigerian Stock Exchange, while foreigners accounted for the remaining 30 percent. Of the N8.91 billion in transactions during that period, 50.41 percent constituted outflows while 49.59 percent was made up of inflows.

In analysing the impact of domestic and foreign investments on external reserves, the paper uses the elasticity of substitution framework. The importance of the elasticity of substitution has been canvassed in the literature and has increasingly become a key parameter in international economics for assessing or measuring the substitutability between inputs to a production or utility function. It has, however, not received enough attention in studies relating to domestic and foreign investment. In the light of this, the paper investigates how Nigeria's external reserves responds to the behaviour of foreign and domestic investment in the country. Thereby showing the kind of deliberate monetary policy adjustments that should be pursued overtime to achieve stability. The reaction is fundamental to a spectrum of policy challenges and decisions

in the conduct of monetary policy in Nigeria, particularly as it affects, balance of payments adjustments and the pass-through effect of monetary policy to exchange rate (Auer & Schoenle, 2016).

From our search in the literature available to us, there are no previous studies on Nigeria's external reserve and the elasticity of substitution between domestic and foreign investment in Nigeria. Therefore, findings from the study on "External Reserve and the Elasticity of Substitution between Domestic and Foreign Investment in Nigeria" hold significant value for both the monetary authority and the federal government. For the monetary authority, the results will provide critical insights into how investment patterns – foreign or domestic, influences the accretion of depletion of external reserves in Nigeria. Understanding the elasticity of substitution between domestic and foreign investments allows the Central Bank of Nigeria (CBN) to better manage foreign exchange reserves, optimize exchange rate policies, and create an environment that encourages balanced investment flows. The study's findings will guide the CBN in implementing policies that stabilize the Naira, mitigate the impact of external shocks, and enhance investor confidence, which is essential for attracting both domestic and foreign investments. For the federal government, the study offers valuable contributions to economic planning and policy formulation. The insights gained from the elasticity of substitution can help the government design more effective strategies to stimulate domestic investment while also attracting foreign capital. By understanding the factors that influence investors' decisions to allocate capital between domestic and foreign assets, the government can tailor its fiscal policies, incentives, and regulatory framework to create a more competitive and diversified economy. Moreover, the study can inform the government's approach to managing external reserves, ensuring that these reserves are leveraged effectively to support national development goals and economic stability.

Policymakers can gain several important insights from understanding the elasticity of substitution between foreign and domestic investment. This elasticity of substitution approach reveals how sensitive investors are to changes in economic conditions or policy shifts. If the elasticity is high, it means investors can easily switch between foreign and domestic investments depending on which offers better returns or lower

risks. This insight is crucial for policymakers, as it shows that small changes in policies—such as tax rates, interest rates, or regulatory frameworks—can significantly influence where investors choose to allocate their capital. Understanding this sensitivity allows policymakers to design more effective strategies to attract and retain investment.

Following this introduction, section 2 reviews both the theoretical and empirical literature on elasticity of substitution. The data and methodology adopted for the analysis are discussed in section 3, while section 4 deals with the empirical results and analysis. The conclusion and recommendations are presented in section 5.

2.0 Literature Review

2.1 Theoretical Literature

Traditionally, external reserves are viewed as a buffer against external shocks, such as sudden stops in capital flows, currency crises, or balance of payments problems. According to the Buffer Stock Model, reserves act as insurance, enabling countries to smooth consumption and investment during periods of economic instability (Frenkel & Jovanovic, 1981). In this framework, both foreign and domestic investments are important. While foreign investments are often prioritized due to their direct impact on the balance of payments and the need to maintain reserve adequacy, domestic investments have also shown a great deal of importance, as it helps to ramp up domestic productivity and provide avenue for import substitution of foreign product which hitherto would warrant external reserves depletion. The Precautionary Motive Theory also emphasizes the importance of foreign reserves in providing a safeguard against external vulnerabilities (Aizenman & Marion, 2003). This theory suggests that countries with higher exposure to volatile capital flows, particularly from foreign investments, are more likely to accumulate larger reserves to mitigate risks.

Elasticity of Substitution between Domestic and Foreign Investments

The elasticity of substitution between domestic and foreign investments plays a crucial role in determining the sources of external reserves. If foreign investments are highly substitutable with domestic investments, a country may rely on foreign capital inflows to build reserves. However, if the elasticity of substitution is low, domestic

investments may become more significant, especially in cases where foreign investments are volatile or risky. In the context of developing economies, Mundell (1963) posits that foreign investments can have a multiplier effect on external reserves, as they directly influence the balance of payments through foreign exchange earnings. However, Stiglitz and Weiss (1981) argue that imperfections in capital markets, such as information asymmetry and political risks, can limit the substitutability between domestic and foreign investments. In such cases, domestic investment may play a more critical role in supporting long-term economic stability and reserve accumulation.

Foreign Investment and External Reserves

Foreign direct investment (FDI) is often seen as a stable and long-term source of foreign exchange, contributing directly to external reserves through capital inflows. The literature suggests that FDI has a significant impact on external reserves, particularly in developing countries where domestic savings are insufficient to finance investment needs. Bosworth and Collins (1999) argue that FDI not only provides foreign exchange but also enhances productivity and economic growth, which can lead to sustained reserve accumulation. However, the benefits of FDI depend on the host country's economic environment and policy framework. Rodrik (1998) notes that FDI can sometimes be volatile and subject to sudden reversals, although not as much as portfolio investment will. This is particularly common in countries with very weak institutions or political instability. In such cases, the contribution of FDI to external reserves may be undermined by capital flight or currency depreciation.

On the other hand, portfolio investments, such as equity and bond inflows, are another source of foreign exchange that can contribute to external reserves. However, portfolio investments are typically more volatile than FDI, making them a less reliable source of reserve accumulation. Calvo and Reinhart (2000) highlight the "sudden stop" phenomenon, where large inflows of portfolio capital can quickly reverse, leading to significant pressures on external reserves.

The literature also points to the role of financial market integration in influencing the elasticity of substitution between domestic and foreign investments. In countries with

well-developed financial markets, portfolio investments may be more substitutable with domestic investments, leading to greater flexibility in reserve management. However, in developing economies like Nigeria, where financial markets are relatively less developed, the reliance on foreign portfolio investment can increase external vulnerabilities.

Domestic Investment and External Reserves

Domestic investment is crucial for sustainable economic growth, which in turn can support the accumulation of external reserves. According to the Solow Growth Model (*Solow, 1956*), domestic investment in physical and human capital drives long-term economic growth, which can lead to increased export capacity and foreign exchange earnings. In this context, domestic investment indirectly contributes to external reserves by enhancing a country's export competitiveness and reducing its reliance on foreign capital.

The Role of Domestic Savings

The relationship between domestic savings and investment is also critical in understanding the role of domestic investment in external reserves. The Feldstein-Horioka Puzzle (Feldstein & Horioka, 1980) suggests that in a closed economy, domestic investment is largely financed by domestic savings. However, in an open economy, the correlation between domestic savings and investment weakens, as capital flows across borders. In Nigeria, the low level of domestic savings often necessitates reliance on foreign investment to finance domestic investment, which can affect the accumulation of external reserves.

Domestic investment can also play a role in ensuring reserve adequacy by reducing the need for external borrowing. For instance, investments in sectors that generate foreign exchange, such as agriculture and manufacturing, can reduce the country's dependence on external financing and support reserve accumulation. Krugman (1979) emphasizes the importance of developing domestic industries to enhance export capacity and reduce external vulnerabilities, which in turn supports the accumulation of external reserves.

Comparative Analysis: Foreign vs. Domestic Investment in Reserve Accumulation
One of the key distinctions between foreign and domestic investment is the level of volatility associated with each. Foreign investments, particularly portfolio flows, are subject to global financial conditions and can be highly volatile, posing risks to reserve stability. In contrast, domestic investments are generally more stable and less prone to sudden reversals, making them a more reliable source of long-term growth and reserve accumulation. However, foreign investments, especially FDI, can bring in much-needed foreign exchange and technology, which can boost productivity and exports. This, in turn, can lead to a faster accumulation of external reserves compared to relying solely on domestic investments.

2.1.1 The Cobb-Douglas Production Function and Elasticity of Substitution

The Cobb-Douglas production function adopts the elasticity of substitution concept as a parameter to measure the substitutability between labour and capital inputs in events of their price changes, while keeping output level constant. The Constant Elasticity of Substitution (CES) production function nests numerous forms of technology based on the value of elasticity. For instance, the well-established Cobb-Douglas production function presupposes a unitary elasticity of substitution between capital and labour. The functional form of the Cobb-Douglas production function also assumes constant capital (and labour) share of income, referred to as the Kaldor factor (Kaldor, 1957). However, in recent times, the labour share has decreased in the advanced economies (Elsby, Hobijn, & Sahin, 2013; Karabarbounis & Neiman, 2013) Piketty & Zucman (2014) relate this to be above unitary value of elasticity of substitution. With elasticity (σ) >1 indicating that labour and capital are easily substitutable and hence, if the relative cost of either of the two factors changes, production substitute away from the costlier factor to the less expensive one. This, in turn, will lead to greater utilization of less expensive inputs in production, increasing the share of income allocated to such inputs. Consequently, understanding the value of elasticity becomes crucial for analyzing trends in income distribution among production factors.

The intuition behind the multiple empirical literature on elasticity have been to determine if the elasticity value is exactly unitary, below or above unitary. The agreement on the elasticity value is important for understanding the evolution of the

substitutability of shares of certain factors of production. The Armington's (1969) model of substitution further elaborates the argument of elasticity of substitution by measuring consumers' optimization in substituting between domestic and foreign goods.

2.1.2 The Allen and Morishima Elasticity of Substitution

The concept of elasticity of substitution (Ω) as originally introduced by Hicks (1932), made use of only two inputs ($x_1 \; and \; x_2$), and is thus defined as

$$\Omega = \frac{dln(X_2/X_1)}{dln(P_1/P_2)} \tag{2.1}$$

where p_i is the price of input X_i. The elasticity of substitution provides a very important information in computing the relative responsiveness of inputs to changes in prices. Hicks (1932) assumption is restricted to a production line with only two inputs required for production. His model cannot be applied to a situation where there are more than two inputs for production.

In a unique case of more than two inputs, a conventional measure of substitution is the Allen Partial Elasticity of Substitution (AES) developed by Allen (1938). From Chun and Hyunbae (2006), the AES between two inputs in a cost combination of α and β, for a 2 times differential cost function (C), is defined as

$$\Omega^A_{\alpha\beta} = \frac{C.C_{\alpha\beta}}{C_\alpha.C_\beta} \tag{2.2}$$

where the subscripts denote partial derivatives with respect to input prices. The inputs α and β are regarded as Allen substitutes if $\Omega^A_{\alpha\beta} > 0$ and Allen complements if the inequality is reversed. Adopting Shepard's lemma, the Allen Elasticity of Substitution could be written as

$$\Omega^A_{\alpha\beta} = \frac{\varepsilon_{\alpha\beta}}{S_\beta} \tag{2.3}$$

where $\varepsilon_{\alpha\beta}$ represents the cross-price elasticity (CPE) of demand for input α with respect to the price of input β, and S_β is the share cost of β. Equation (2.3) shows that the Allen Elasticity of Substitution does not give further information concerning the pattern of input substitution relative to the cross-price elasticity. Additionally, Equation (2.3) may suggest that the AES is not an appropriate measure of substitution, rather, Chun (2006) added that an alternative measure of substitutability is the

Morishima elasticity of substitution (MES), which is defined in a form of a cost function as shown below.

$$\Omega_{\alpha\beta}^{M} = \frac{P_\beta C_{\alpha\beta}}{C_\alpha} - \frac{P_\beta C_{\beta\beta}}{C_\beta} \quad (2.4)$$

In determining the appropriate measure of substitutability, Blackorby and Russell (1989) show that the MES is a more appropriate measure of the degree of substitutability compared to AES, reason being that MES measure exact response of the ratio of input to change in price.

The Morishima Elasticity of Substitution in Equation 4 is further expressed in terms of the cross- and own-price elasticities as shown below

$$\Omega_{\alpha\beta}^{M} = \varepsilon_{\alpha\beta} - \varepsilon_{\beta\beta} \quad (2.5)$$

where $\varepsilon_{\beta\beta}$ indicates the own-price elasticity of input β. Therefore, the Morishima Elasticity of Substitution measures the percentage in the ratio of input α vis-à-vis input β, given a one-percent change in the price of input β.

The Morishima Elasticity of Substitution is not symmetric, in contrast to the Allen Elasticity of Substitution, because changes in the input influenced by the price of input β are in contrast from those influenced by the price of input α. It is also worthy of note that the Allen complements ($\Omega_{\alpha\beta}^{A} < 0$) can be Morishima substitute ($\Omega_{\alpha\beta}^{A} > 0$), if $\varepsilon_{\alpha\beta} < 0$ and $|\varepsilon_{\alpha\beta}| < |\varepsilon_{\beta\beta}|$. On the other hand, the Allen substitutes are always Morishma substitutes. Therefore, the Morishima Elasticity of Substitution more regularly classifies two inputs as substitute than the Allen Elasticity of Substitution does.

Therefore, the Morishima Elasticity of Substitution can be used in estimating the level of elasticity between domestic and foreign investment in Nigeria by substituting foreign and domestic investment into equation (3), which becomes:

$$ER = \frac{di}{fi} \quad (2.6)$$

where

ER= External Reserve

DI= Domestic Investment

FI= Foreign Investment.

We adopt the elasticity of substitution of domestic investment to foreign investment as presented in equation (2.1) to further appraise possibility of ascertaining the combination of investment type that promotes external reserves accretion in Nigeria.

2.2 Empirical Literature

In seeking to measure the elasticity of substitution between domestic and foreign goods, Bajzik et al. (2019) provided a thorough examination of the elasticity of substitution between domestic and foreign goods in international trade. The study employed the Armington elasticity parameter, a crucial tool for understanding how easily goods produced domestically can be substituted with foreign goods. By analyzing a vast dataset of 3,524 estimates, the study aimed to build a comprehensive understanding of the factors influencing elasticity. Bajzik et al. utilized both Bayesian and frequentist model averaging to address inherent uncertainties within their models. The findings were multifaceted: the study uncovered a bias against small and statistically insignificant elasticities, highlighted the importance of data differences (such as frequency, aggregation dimension, and size) in explaining variations in results, and determined that the mean elasticity, after correcting for publication bias and potential misspecifications, stood at 3. This study underscores the complexity of measuring elasticity and the critical role that methodological choices play in deriving reliable estimates.

Polat (2015) approached the topic from a different angle, focusing on the relationship between FDI and domestic investment in 30 OECD countries from 2006 to 2013. His study challenged previous findings that presented mixed and controversial evidence on whether FDI crowds out or crowds in domestic investment. By employing the one-step Generalized Method of Moments (GMM) system, Polat was able to reveal that while overall FDI inflows do not significantly impact domestic investment, intra-country loans, a sub-component of FDI, do positively affect domestic capital formation. This insight emphasizes the importance of considering the structure of FDI when assessing its impact on domestic investment.

Wang (2019) offered further insights by investigating the relationship between foreign direct investment and foreign reserve accumulation using a small economy model. His

study integrated domestic entities and international investors to explain the level of reserves and the associated capital flows. The model suggested a positive co-movement between technology growth and the current account, with findings indicating that high technology growth corresponds to net capital outflow. This result is particularly relevant for understanding how technological advancements can drive capital movement and influence foreign reserve levels, providing a rationale for the allocation puzzle observed across different economies.

Ijirshar et al. (2019) extended the exploration of FDI and domestic investment by focusing on a panel of 41 selected African countries over the period from 1970 to 2017. The study employed the pooled mean group (PMG), dynamic panel models, and Mean Group (MG) estimators to analyze the growth-differential effects of FDI and domestic investment. The findings revealed that both FDI and domestic investment are critical for the long-term growth of African countries. Notably, the study discovered that FDI inflows tend to crowd in domestic investment in Africa, although there were significant differences in their growth effects. In the short run, however, FDI negatively impacted growth in some countries, while domestic investment had a positive effect. This study underscores the complex and context-dependent nature of the relationship between FDI, domestic investment, and economic growth in African countries.

Chhimwal and Bapat (2020) shifted the focus to the impact of foreign and domestic investment on stock market volatility in India. Using ARMA (1,1) and TGARCH (1,1) models, the authors explored how unexpected domestic institutional investments and foreign portfolio investment flows influence the volatility of stocks in different capitalization segments. The study found that unexpected foreign portfolio investment inflows increase market volatility, but this effect is moderated by the unexpected flows of domestic institutional investments. Interestingly, the study also noted that the impact of unexpected selling by foreign portfolio investors was more pronounced than that of unexpected purchases, particularly in the small-cap stock segment. This highlights the differential impact that foreign and domestic investments can have on market stability, depending on the market segment and the nature of the capital flows.

Several other studies have contributed to understanding the determinants of external reserve accumulation, recognizing the critical role that reserves play in maintaining macroeconomic stability. For example, Irefin and Yaaba (2011) utilized an Autoregressive Distributed Lag (ARDL) model to explore the determinants of external reserves in Nigeria. Their analysis focused on key variables such as the monetary policy rate, income, exchange rate, and imports. The study refuted the existence of a buffer stock model for external reserves accumulation and provided evidence that income is a significant determinant of reserves in Nigeria. Similarly, Osigwe et al. (2015) investigated the long-run relationships between macroeconomic variables and external reserves in Nigeria, finding that real GDP and oil exports positively and significantly influence the level of reserves, while the exchange rate has a significant but negative impact. These studies collectively emphasize the importance of both domestic and international factors in shaping external reserve levels, with implications for economic stability and policy formulation.

The existing empirical literature has extensively explored the determinants of external reserves in Nigeria, contributing significantly to our understanding of the factors that influence reserve accumulation. However, there remains a notable gap in the research regarding the elasticity of substitution between domestic and foreign investments, particularly in the context of external reserve buildup. Specifically, there has been limited focus on assessing the elasticity of substitution between foreign direct investment (FDI) and foreign portfolio investment (FPI) and their respective roles in the accumulation of external reserves. This study aims to address this gap, providing new insights into the field of external reserves management, with a particular emphasis on the interplay between FDI and FPI and their impact on reserve accumulation.

3.0 Methodology

3.1 Data

Our study makes use of monthly time series data, ranging from January 2008 to December 2023, obtained from the Central Bank of Nigeria (CBN) Statistical Bulletins and Databases. The variables include monthly external reserves (ER), the real domestic investment proxied by gross fixed capital formation (GCF), and foreign investments - disaggregated into foreign portfolio investments (FPI) and foreign direct

investments (FDI). Our preference for gross capital formation to represent total domestic direct investment stems from the fact that the implementation of government's annual capital expenditure will filter down to private investments in the acquisition of assets such as equipment, tools, and buildings, which makes up the gross capital expenditure. The gross fixed capital formation was initially obtained in quarterly form but was transformed into monthly data using a quadratic sum model for the purpose of uniformity with the other variables.

3.2 Model Specification

The objective of this study is to assess the impact of different types of investment flows on Nigeria's external reserve movements, focusing on the elasticity of substitution between domestic and foreign investments from 2008 to 2023. In doing this, the dynamic relationships between external reserves (EXTRES) and its potential determinants, namely foreign direct investment (FDI), foreign portfolio investment (FPI), gross capital formation (GCF). To achieve this, we employ the Autoregressive Distributed Lag (ARDL) bounds testing approach to cointegration, as developed by Pesaran et al. (2001). This methodology is particularly suitable for our study due to its ability to handle a mix of variables that are integrated of order I(0) and I(1), addressing concerns of pre-testing for unit roots, which is a precondition for traditional cointegration techniques such as the Johansen cointegration test.

The ARDL bounds testing approach is chosen due to several advantages it offers over alternative econometric methods. One of the key advantages of the ARDL approach is its flexibility regarding the stationarity properties of the variables. The ARDL model can accommodate variables that are either integrated of order zero [I(0)] or integrated of order one [I(1)], without requiring all variables to be of the same order of integration (Pesaran et al., 2001). This is crucial for our dataset, where preliminary tests suggest a mix of I(0) and I(1) variables. Additionally, the ARDL approach performs well even in small sample sizes (Narayan, 2005), which makes it particularly useful for the present study where we have a relatively limited number of observations. Furthermore, the model allows for the simultaneous estimation of both short-run and long-run dynamics. This is essential for understanding the immediate impacts of FDI, FPI and

GCF on external reserves (EXTRES), as well as the long-run equilibrium relationship among the variables (Pesaran et al., 2001).

Once cointegration is confirmed, the ARDL model provides a straightforward error correction model (ECM) representation. This makes it easy to interpret the speed of adjustment back to the long-run equilibrium following a short-run disturbance (Engle & Granger, 1987).

In our model, we selected some variables that the external reserves could respond to their individual changes in line with apriori expectations. Thus, we propose that the variables are combined to form a functional equation as stated below:

$$EXTRES_t = \alpha_0 + \alpha_1 FDI_t + \alpha_2 FPI_t + \alpha_3 GCF_t + \varepsilon_t \quad (3.1)$$

Where:

EXTRES = Nigeria's External Reserves

FDI = Foreign Direct Investment

FPI = Foreign Portfolio Investment

GCF = Gross Capital Formation

α are the coefficients which explains the elasticity of the variables with respect to external reserves

ε_t *represents the residuals*

Table 1: The A Priori Expectations of the Variables Used in the Model

S/N	VARIABLES	VARIABLES NOTATIONS	MEASUREMENTS	A PRIORI EXPECTATION
1	External Reserves	EXTRES	US$ Billion	+ve
2	Foreign Direct Investment	FDI	US$ Billion	+ve
3	Foreign Portfolio Investment	FPI	US$ Billion	+ve
4	Gross Capital Formation	GCF	N'Billion	+ve

The ARDL model for the short-run relationship between external reserves (EXTRES) and its determinants is specified as follows:

$$\Delta lnEXTRES_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i} \Delta lnEXTRES_{t-i} + \sum_{i=0}^{n} \alpha_{2i} \Delta\, lnFDI_{t-i} + \sum_{i=0}^{n} \alpha_{3i} \Delta\, lnFPI_{t-i} + \sum_{i=0}^{n} \alpha_{4i} \Delta\, lnGCF_{t-i} + \beta_1 lnEXTRES_{t-i} + \beta_2 lnFDI_{t-i} + \beta_3 lnFPI_{t-i} + \beta_4 lnGCF_{t-i} + \varepsilon_t \ldots\ldots\ldots\ldots \quad (3.2)$$

Where:
Δ *denotes the first difference operator*
α_0 *is the constant term,* ε_t *represents the intercept*
α_1 - α_4 *are short-run dynamic coefficients of the model*
$\beta_1 - \beta_4$ *are the long-run relationships*

If cointegration is established, the long-run relationship can be expressed as:

$$lnEXTRES_t = \partial_0 + \partial_2 lnFDI_t + \partial_3 lnFPI_t + \partial_4 lnGCF_t + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.3)$$

Where
∂_0 represents the intercepts while ∂_1, ∂_2, ∂_3 and ∂_4 are the long run coefficients and ε_t is the error term. Once the long-run relationship is confirmed, the corresponding error correction model (ECM) is specified as follows:

$$\Delta lnEXTRES_t = \alpha_0 + \sum_{i=1}^{n} \alpha_{1i} \Delta lnEXTRES_{t-i} + \sum_{i=0}^{n} \alpha_{2i} \Delta\, lnFDI_{t-i} + \sum_{i=0}^{n} \alpha_{3i} \Delta\, lnFPI_{t-i} + \sum_{i=0}^{n} \alpha_{4i} \Delta\, lnGCF_{t-i} + \emptyset ECM_{t-1} + \varepsilon_t \ldots \quad (3.3.3)$$

Where ECM_{t-1} is the error correction term derived from the long-run cointegrating relation, and $\emptyset$ represents the speed of adjustment parameter. A negative and

significant ∅ confirms the existence of a long-run equilibrium relationship and indicates the speed at which deviations from this equilibrium are corrected.

3.3 Estimation procedure

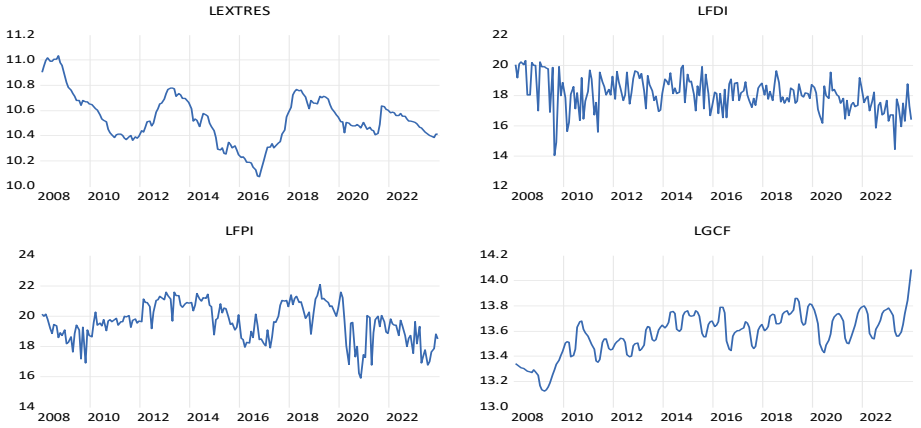
Before estimating the ARDL model, the stationarity of the variables will be tested using the Augmented Dickey-Fuller (ADF) test and the Phillip-Perron (PP) test to determine the order of integration of the variables. Also, the appropriate lag length for the ARDL model will be determined using information criteria such as the Akaike Information Criteria (AIC) or Schwarz Bayesian Criterion (SBC), ensuring that the model adequately captures the dynamics of the data without overfitting.

Next step involves conducting the bounds test for cointegration. The null hypothesis of no cointegration will be tested against the alternative hypothesis of cointegration using F-statistics. If the F-statistics exceeds the upper critical bound, we reject the null hypothesis, indicating the existence of long-run relationship between external reserves and its determinants. Furthermore, if cointegration is established, we proceed to estimate both the short-run and long-run coefficient of the ARDL model, along with the error correction term. Having completed the estimation, the diagnostics tests, such as the Breusch-Godfery serial correlation LM test and Breusch-Pagan-Godfery heteroskedasticity test, will be conducted to ensure that the model satisfies the necessary assumptions. Additionally, the CUSUM and CUSUMSQ test will be used to assess the stability of the model over time.

4.0 Empirical Findings

Traditionally, in most time series econometric analysis, the first step is to analyze the statistical properties and characteristics of the data especially as it relates to trend, direction of trend, existence of structural breaks and stationarity. The natural log form of the variables used in the model are presented in Figure 6 below. The figure shows that the logs of foreign direct investment (FDI), foreign portfolio investment (FPI), and external reserve (LEXTRES) and log of gross capital formation (LGCF) did not exhibit any deterministic trend. No distinct structural breaks were identified in the graphical presentation except three episodes of downward-like structural breaks observed in the external reserves (LEXTRES).

Figure 1: Variables Included in the ARDL Model



The descriptive statistics for the variables LEXTRES, LFDI, LFPI, and LGCF show that their means and medians are relatively close, indicating a symmetric distribution for most variables. LEXTRES has a mean of 10.54 and a standard deviation of 0.19, suggesting that external reserves fluctuate moderately around their mean, with a skewness of 0.26, indicating a slightly positive skew. The maximum and minimum values range from 11.04 to 10.07, highlighting limited variability in external reserves. LFDI, LFPI, and LGCF exhibit higher variability compared to LEXTRES, with standard deviations of 1.14, 1.24, and 0.17, respectively. Both LFDI and LFPI are negatively skewed, while LGCF is also moderately negatively skewed, indicating that their distributions are slightly skewed to the left. The Jarque-Bera statistics for LFDI, LFPI, and LGCF are statistically significant (p-values of 0.02), suggesting deviations from normality, while LEXTRES does not reject normality (p-value of 0.31). All variables show a consistent number of observations (192), which ensures reliability in the descriptive analysis.

Table 2: Some Descriptive Statistics

	LEXTRES	LFDI	LFPI	LGCF
Mean	10.54	18.08	19.59	13.58
Median	10.52	18.07	19.66	13.61
Maximum	11.04	20.31	22.07	14.09
Minimum	10.07	14.03	15.90	13.12
Std. Dev.	0.19	1.14	1.24	0.17
Skewness	0.26	- 0.41	- 0.50	- 0.49
Kurtosis	3.13	3.54	2.81	3.24
Jarque-Bera	2.36	7.63	8.34	8.01
Probability	0.31	0.02	0.02	0.02
Sum	2,022.78	3,472.15	3,762.17	2,607.51
Sum Sq. Dev.	7.26	247.55	296.04	5.39
Observations	192	192	192	192

4.1 Pre-Estimation Tests

Unit Root Test

The Augmented Dickey Fuller (ADF) and the Philip Peron (PP) tests statistics with both intercept and trend, were used to examine the existence or otherwise of unit root in the series. We compare the unit root test statistics with the Mackinnon critical values to reject or accept the hypothesis that unit root exists. The variables chosen indicated statistical significance ranging from 1 to 5 per cent critical values. The test results are shown in Table 3. The hypothesis is formulated thus:

Ho: $\theta = 1 - 5$ (Non-stationary)

H1: $\theta < 1 - 5$ (stationary)

Table 3: Result of the Unit Root Test for Stationarity

	Augmented Dickey Fuller (ADF)			**Phillip Perron (PP)**		
	Levels	First Difference	Order of Integration	Levels	First Difference	Order of Integration
LEXTRES	-2.29	-10.05***	I(1)	-2.21	-10.37***	I(1)
LFDI	-11.52***		I(0)	-11.66***		I(0)
LFPI	-3.81***		I(0)	-4.93***		I(0)
LGCF	-3.74**		I(0)	-2.71	-7.23***	I(1)

NB: *, ** and *** Indicates statistical significance @ 10%,5% and 1%, respectively

4.2 Bounds Cointegration Test

The study adopts the ARDL Bound test to measure whether the model variables are cointegrated. Having established the order of integration, a long-run relationship between the variables were tested using the bounds test. From Table 4, the result of the bounds test indicates solid evidence of a long-run relationship between the variables compared with the critical values as prescribed by Pesaran et al (2001) at the lower and upper bounds. The F-statistics at 1.0, 5.0 and 10.0 per cent level of significance are greater than the upper bound critical value. We therefore conclude that there exists a long-run relationship between external reserves and its determinants as provided in the model. Based on the foregoing, our model is estimated using the ARDL co-integration technique to obtain both short-run and long-run estimates.

Table 4: Result of the Bounds Test

Test Statistic	**Value**	**Signif.**	**I(0)**	**I(1)**
			Asymptotic: n=1000	
F-statistic	4.13	10%	2.37	3.20
		5%	2.79	3.67
		1%	3.65	4.01

4.3 Results of the Long-run Regression Estimates

Table 5 presents the results of the ARDL estimation, capturing both the long-run dynamics. Notably, the results indicate that the coefficient of gross capital formation is negative (-0.7131), which is contrary to the expected sign. Despite this deviation from theoretical expectations, the coefficient is statistically significant at the 5.0 percent level. This suggests that during the review period, gross capital formation had a negative impact on the Nigeria's external reserves. This negative relationship between gross capital formation and external reserves can be attributed to several factors. One key explanation lies in the persistent inadequacy of infrastructure and public goods, which are essential for fostering investor confidence and attracting both domestic and foreign investment—especially critical investments for an emerging and developing economy like Nigeria. Additionally, the Nigerian economy is heavily driven by the public sector, with significant reliance on the monthly Federal Account Allocation Committee (FAAC) disbursements to finance capital projects, which contribute to gross capital formation. Over the past two decades, government capital expenditure in Nigeria has consistently remained below 30.0 percent of the total annual budget (CBN Statistical Bulletins), despite clear evidence pointing to the need for increased capital spending to drive growth and development. The long-run ARDL result presented in Table 5 further revealed that the coefficient of FPI was positive as predicted by the a priori at 0.0844 and was statistically significant at 5.0%, implying that a 1.0 percent increase in foreign portfolio investment will lead to the accretion of external reserves to the tune of 0.0844 percent. Additionally, the outcome the foreign direct investment (FDI) indicated a negative relationship between the FDI and external reserves. Even though a priori expectation indicated that FDI should lead to accumulation of reserves, the result indicated that the coefficient of FDI is negatively signed at -0.0061, and was statistically insignificant at 0.8737, further indicating that there is no long-run relationship between FDI inflows and the external reserves during the period under review. It can be adduced from this result that the dearth of domestic infrastructural development coupled with incoherent government policies hampers investors' confidence to invest in the Nigerian economy. On the other hand, the foreign portfolio investment as presented in Table 5 below exhibited the right sign and statistically significant. Meanwhile the F-statistics of the model as shown in the bounds test reflects the long-run relationship among the variables based on whether it

is greater or lower than the critical value. The result in Table 4 shows that the F-Statistics (4.13) is greater than the lower and upper bounds, indicating the overall significance of the model in the long run.

Table 5: Long-run Estimates of the ARDL Model

Dependent Variable: LEXTRES				
Variable *	Coefficient	Std. Error	t-Statistic	Prob.
LFDI	-0.0061	0.0386	-0.1592	0.8737
LFPI	0.0844	0.0359	2.3490	0.0199
LGCF(-1)	-0.7131	0.2778	-2.5669	0.0111
C	18.6396	3.8722	4.8137	0.0000

4.4 ARDL Error Correction Regression

Estimating the Error Correction Model (ECM) allows us to understand the short-run dynamics in relation to the long-run equilibrium. The ECM results presented in Table 6 show that the coefficient of the error correction term is -0.0593. This coefficient is correctly signed and statistically significant at the 1 percent level. For the ECM to be valid, the coefficient of the cointegration equation must be negative, indicating the speed at which the system adjusts from short-term disequilibrium back to the long-term equilibrium. In this case, the negative sign of the ECM coefficient suggests that any disequilibrium in external reserves caused by a shock in the previous month will be corrected by 0.0593 percentage change in the following month, moving the system toward its long-term equilibrium. The results indicate that most variables in the model are statistically significant, and their coefficients generally have the expected signs, though a few lagged variables displayed unexpected signs while still being statistically significant.

Table 6: ARDL Error Correction Model (ECM)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ECM(-1)*	-0.0593	0.0141	-4.2157	0.0000
LFDI**	-0.0004	0.0023	-0.1597	0.8733
LFPI**	0.0050	0.0021	2.3965	0.0176
LGCF(-1)	-0.0423	0.0175	-2.4133	0.0168
C	1.1059	0.3219	3.4357	0.0007
D(LEXTRES(-1))	0.2439	0.0710	3.4352	0.0007
D(LEXTRES(-2))	0.0585	0.0737	0.7940	0.4282
D(LEXTRES(-3))	0.1594	0.0711	2.2426	0.0262
D(LGCF)	-0.0647	0.0467	-1.3864	0.1674
D(LGCF(-1))	0.1130	0.0484	2.3358	0.0206

4.5 Post- Estimation Test for the Model

The diagnostic test for possible presence of serial correlation and heteroskedasticity in the model is presented in Table 7. The null hypothesis of these tests is that heteroskedasticity and serial correlation exist in the model. The result of the serial correlation indicates the rejection of the null hypothesis given that the p-value of the F-statistics of the Breusch Godfrey test as well as the test for heteroskedasticity using the Breusch Pagan test are greater than 0.05 level of significance. Thus, the specification of the model is free from heteroskedasticity and serial correlation. Furthermore, the model was tested for misspecification using Ramsey RESET test as shown in Table 8. The Ramsey Reset test shows that for all test statistics at 0.05 level of significance, the null hypothesis of no misspecification error is accepted. Therefore, the model used in this study is well specified.

Table 7: Breusch-Godfrey Serial Correlation and Heteroskedasticity Diagnostics Test

	F-statistic (p-value)	Obs*R-squared Prob. Chi-square)
Serial Correlation Test	0.0839(0.9195)	0.1791(0.9143)
Heteroskedasticity Test	0.7137(0.6958)	6.5478(0.6840)

Table 8: Ramsey Reset Test

	Value	df	Probability
t-statistic	0.45640	177	0.64865
F-statistic	0.20830	(1, 177)	0.64865
Likelihood ratio	0.22112	1	0.63818

An additional test for stability was conducted using the CUSUM and CUSUMSQ as developed by Brown et al (1975). This was to incorporate the short-run dynamics for consistency of long-run parameters. The stability of the long-run coefficients was used for error term correction. Figure 2 and 3 shows the plot of CUSUM and CUSUMSQ which indicates that the statistics lie within the 5.0 per cent critical bounds further emphasizing that the coefficient of the model is stable.

Figure 2: Plot of CUSUM

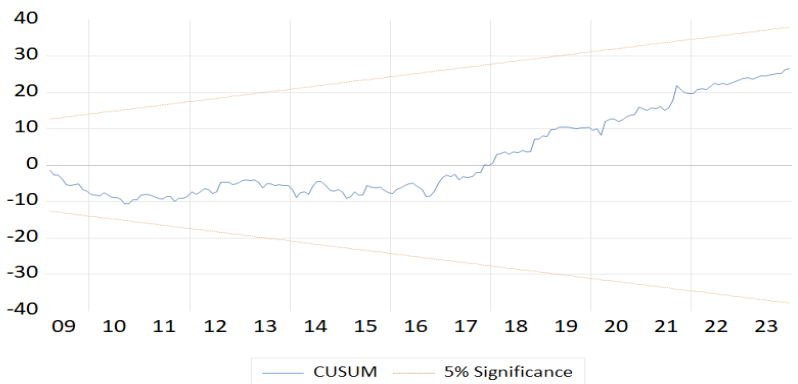
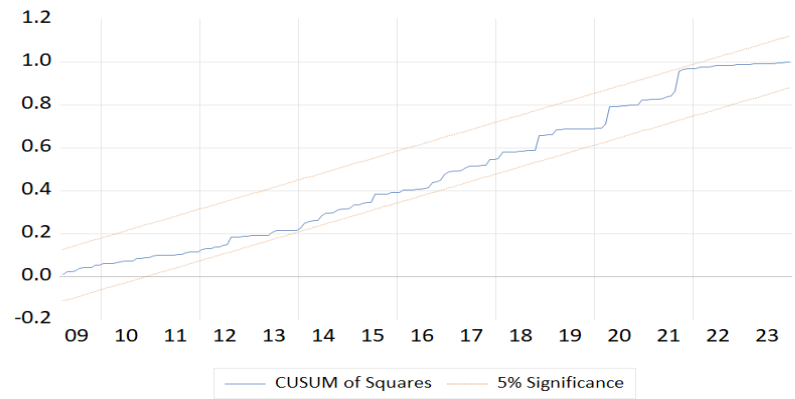


Figure 3: Plot of CUSUMSQ



4.6 An Application of Elasticity of Substitution

To determine the elasticity of substitution between the domestic and foreign investments in Nigeria, the Morishima Elasticity of Substitution was applied, as estimated in equation 2.6 on the result of the ARDL estimation. Given the foregoing, the gross capital formation as a proxy for domestic investment is the numerator, while the foreign investments (direct and portfolio) were the denominators. On the other hand, to determine the converse of the elasticities, the inverse of the former was computed. From Table 9, the elasticity of substitution between foreign portfolio investment and gross capital formation (domestic investment) is inelastic at -0.11836, implying that the level of external reserves will be negatively affected if there is a deliberate policy to pursue a substitution of investment from domestic investment (GCF) to foreign portfolio investment (FPI). An elasticity of substitution of FPI with GCF also resulted to an inelastic position but with a higher degree of responsiveness at -8.44905. In both scenarios, the response of external reserves when substituting either FPI for GCF or GCF for FPI will result to inelastic position (Negatively affect the external reserves).

The elasticity of substitution between GCF and FDI is elastic, and the degree of external reserves responsiveness is 116.90, implying that if the government pursue a

policy to promote domestic investment over foreign direct investment, it will lead to massive improvement in the level of external reserves accretion. Lastly, the elasticity of substitution between FDI and GCF i.e. substituting domestic investment with foreign direct investment is perfectly inelastic at 0.0085, implying that the external reserves is constant and remains insensitive to the substitution effect between FDI and GCF.

Table 9: Level of Elasticity of Substitution using Morishima Elasticity of Substitution

Variables	Coefficients	Level of elasticity	Remark
$\frac{LFPI}{LGCF}$	$0.0844/-0.7131$	-0.11836	Inelastic
$\frac{LGCF}{LFPI}$	$-0.7131/0.0844$	-8.44905	Inelastic
$\frac{LGCF}{LFDI}$	$-0.7131/-0.0061$	116.90	Elastic
$\frac{LFDI}{LGCF}$	$-0.0061/-0.7131$	0.0085	Perfectly inelastic

5.0 Conclusion

5.1 Summary

This paper investigates the elasticity of substitution between domestic and foreign investment in Nigeria, highlighting a key issue for emerging economies that rely heavily on foreign capital to build external reserves. The study examined the degree elasticity of substitution between domestic investment and foreign investment on external reserves of Nigeria.

The analysis began by estimating a model for external reserves using the autoregressive distributed lag (ARDL) approach, which helped determine how changes in domestic and foreign investment affect reserves. The study used the ARDL

bounds test to explore the relationships among external reserves, domestic investment (represented by gross capital formation), and the two main types of foreign investment (foreign portfolio investment and foreign direct investment). The results showed that foreign portfolio investment (FPI) had a positive and significant long-run impact on external reserves, suggesting that encouraging FPI could increase reserves over time. In contrast, foreign direct investment (FDI) was found to have a negative and statistically insignificant effect, likely due to insufficient investment in capital goods within the country, which hampers productive activity. Interestingly, the coefficient for gross capital formation was unexpectedly negative, though statistically significantThe unexpected negative coefficient for gross capital formation (GCF) in the study could reflect structural inefficiencies in the Nigerian economy, where domestic investment may not translate effectively into productive output. This could be due to several factors, such as misallocation of resources, high costs of doing business, weak infrastructure, or inefficiencies in the investment process that hinder the expected positive impact on external reserves. For instance, domestic investments might be directed toward non-tradable sectors or projects with limited export potential, which fail to contribute significantly to reserve accumulation.

Additionally, the negative effect might also suggest that increased domestic investment could initially lead to higher importation of capital goods, raw materials, or machinery needed for production, thereby exerting downward pressure on external reserves in the short run. This indicates the need for policies that enhance the efficiency of domestic investments, improve their alignment with export-oriented activities, and reduce reliance on imports during the investment process.The Error Correction Model (ECM) revealed that any imbalance in external reserves caused by shocks would be corrected by 0.593 percent in the following month, indicating a modest adjustment process. The elasticity of substitution results, using the Morishima Elasticity of Substitution indicated that substituting between domestic investment and FPI, or between FDI and domestic investment, does not significantly affect the position of external reserves. However, the substitution between domestic investment and FDI was highly elastic, meaning that focusing on domestic investment could significantly enhance external reserves due to increased export revenues.

5.2 Policy Recommendations

Based on these findings, the paper recommends that the Nigerian government should prioritize domestic investment by expanding revenue sources and increasing capital expenditure. Investing in infrastructure to support domestic private investment and producing goods that can replace imports is crucial. Additionally, despite the low impact of FDI in the short term, it remains a valuable source of capital, so the government should invest in infrastructure to attract more FDI. Finally, monetary policy should focus on creating credit to encourage private sector investment, which will help build and sustain external reserves.

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INFRASTRUCTURE AND MANUFACTURING SECTOR PERFORMANCE IN SUB-SAHARA AFRICAN COUNTRIES

Obianuju Ogochukwu Nnadozie[1], Isiaka Akande Raifu[2 3] and Joshua Adeyemi Afolabi[4]

Abstract

This paper examines the nexus between infrastructure development and manufacturing sector performance in sub-Saharan Africa (SSA). It employs panel data for 38 SSA countries spanning 2003 to 2020 and different panel estimation methods such as the Feasible Generalised Least Square (FGLS) estimator, which is a heteroscedasticity-consistent estimator; the Panel Corrected Standard Error (PCSE) estimator – which corrects for cross-sectional dependence, autocorrelation, and heteroscedasticity; and the two-step Difference Generalised Method of Moments (GMM) technique which accounts for possible endogeneity concerns. Our empirical results indicate that infrastructure development positively and significantly influences manufacturing sector value added. Although, the results are sensitive to an alternative measure of manufacturing sector performance, our empirical findings still give credence to the notion that infrastructure is essential for engendering manufacturing sector performance in SSA. In light of our empirical findings, this study recommends that efforts should be made by governments in the region to improve the level and quality of infrastructure given its capacity to boost manufacturing sector output in SSA.

*All correspondences should be directed to Isiaka Akande Raifu via heritagetiamiyu@gmail.com.

[1]Department of Economics, Faculty of Social Sciences University of Benin, Edo State, Nigeria obianuju.onwukeme@uniben.edu. https://orcid.org/0000-0002-4843-2852

[2]Department of Economics Faculty of Economics and Management Sciences University of Ibadan, Oyo State, Nigeria.

heritagetiamiyu@gmail.com. https://orcid.org/0000-0001-9677-8906

[3]Centre for the Study of the Economies of Africa (CSEA) 1280 Kabir Rabiu Road, Mabushi Federal Capital Territory, Abuja, Nigeria

[4]Innovation and Technology Policy Department, Nigerian Institute of Social and Economic Research, Ibadan, Oyo State, Nigeria

joshuaaafolabi@gmail.com

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1.0 Introduction

Economic diversification has become a recurring policy objective of successive governments in many sub-Sahara African countries, especially the resource-dependent ones. This is due to the increasing realisation that the highly concentrated structure of their production and exports on primary products hurt their global competitiveness and raise their vulnerability to the vagaries of the international market. To achieve the objective of economic diversification, it has been widely acknowledged that the manufacturing sector offers a leeway. The economic success of the Asian Tigers is often cited as a testament to this assertion (Gulati, 1992; Asien, 2015; Aminu, Raifu and Oloyede, 2018).

The manufacturing sector also plays a key role in the industrialization and growth process of any country. This is because the sector offers unique opportunities for capital accumulation, promotes economies of scale by driving technological progress while providing spillover effects through linkages to other economic sectors, displays a higher level of productivity and has more capacity to generate employment compared to other sectors (Efobi and Osabuohien, 2016; Martorano, Sanfilippo and Haraguchi, 2017; Anyanwu, 2018). Again, by fostering productivity and sustainable economic growth, the manufacturing sector can also foster a reduction in poverty and inequality (Ndulu, 2006; Lavopa and Szirmai, 2012). Yet, in SSA where structural and development indicators are lagging behind, the manufacturing sector has not recorded significant improvement.

Within the African continent, several challenges continue to account for poor manufacturing sector performance; one of which is infrastructure. Extant literature attests to the huge infrastructural gap in SSA compared to other developing regions (Yepes, Pierce and Foster, 2008; Foster and Briceno-Garmendia, 2009; Gutman, Sy and Chattopadhyay, 2015, Kodongo and Ojah, 2016; World Bank, 2017). According to Calderon, Cantu and Chuhan-Pole (2018), sub-Saharan Africa ranks at the bottom

of all developing regions in almost all dimensions of infrastructure performance; with a score of 2.91 in the infrastructure category of the World Economic Forum's (WEF's) Global Competitiveness Report. Admittedly, the low level of infrastructure in SSA suggests potential difficulties, not just towards improving manufacturing value added, stimulating industrialization and structural transformation, integrating sub-regional markets for intra-African trade, and positioning of competitive SSA in global markets, but also toward raising the quality of life of the populace and achieving the sustainable development agenda (AfDB, 2020).

Infrastructure is not just an input in the production process; it also complements other factor inputs (Wang, 2002; Kodongo and Ojah, 2016). Thus, it provides productivity enhancements. Reliable infrastructure is crucial for powering businesses, lowering transaction costs, and improving market access and efficiency of other productive factors (Luo and Xu, 2018). In particular, energy infrastructure (electricity) – the lifeblood of manufacturing – is necessary for adding value to raw materials and intermediate products as they are being progressively transformed into final consumer products (Anyanwu, 2018). Transport infrastructure allows for the movement of people and manufactured products in a cost-efficient manner. Information and communication technology (ICT) aids production and exchange by easing the dissemination of information among economic agents (Ismail and Mahyideen, 2015). In sum, infrastructure can boost both the input and the output process in a production system (Efobi and Osabuohien, 2016) allowing for competitiveness in the production of industrial goods. All of these are germane for enhancing manufacturing value added and overall economic performance.

Examining the infrastructure-manufacturing sector performance nexus is fundamental to the achievement of the Sustainable Development Goal (SDG) 9 which is to build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation. Within the African context, the bulk of the existing literature has focused on the growth effects of infrastructure (Fedderke, Perkins, and Luiz, 2006; Ayogu, 2007; Calderon and Serven, 2010; Ajakaiye and Ncube, 2010; Kodongo and Ojah, 2016; Nchofoung, et al. 2022) but extant studies on the impact of infrastructure on manufacturing sector performance in SSA are relatively sparse. The few related

studies in this regard, which employ time-series data mostly, consider only a single infrastructure indicator (Chinedu and Nnadi, 2016; Abokyi et al., 2018; Onwe and King, 2020; Ene et. al, 2022). For those utilizing panel data (Anyanwu, 2018; Mesagan and Bello, 2018; Azolibe and Okonkwo, 2020; Osei & Bentum-Ennin, 2022), issues of autocorrelation, heteroscedasticity, and cross-sectional dependence are mostly ignored. Hoechle (2007) asserts that it is inappropriate to assume cross-sectional independence for the disturbances of a panel data model. Empirically speaking, ignoring possible correlation of regression disturbances over time and across units as well as endogeneity concerns can lead to biased statistical inference. This study, therefore, addresses these important methodological concerns overlooked by previous studies.

Sequel to the above, our empirical strategy follows three different but complementary approaches. First, we employ the Flexible Generalised Least Squares (FGLS) and Panel Corrected Standard Estimator (PCSE) to account for issues of autocorrelation, heteroscedasticity, and cross-sectional dependence. Second, the two-step difference Generalised Method of Moments (GMM) developed by Arellano and Bond (1991) is utilized to address endogeneity concerns or simultaneity bias.

Given this introduction, the rest of the study proceeds as follows. Section 2 presents an overview of manufacturing value added in Africa. A brief review of the literature is documented in section 3 while section 4 contains the model specification and data sources and description. Section 5 presents the empirical results and section 6 contains the conclusion and recommendations.

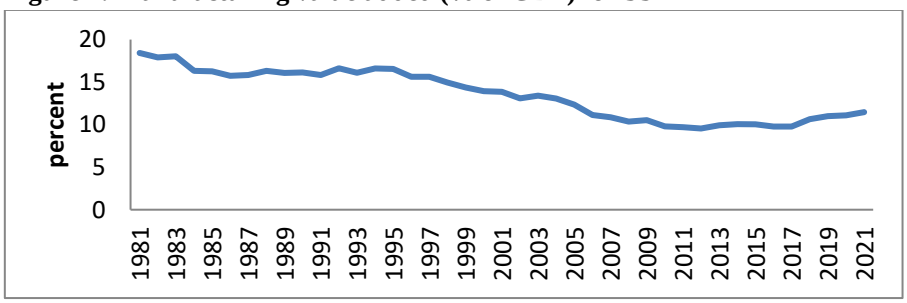
2.0 Overview of Manufacturing Sector Performance and Infrastructural Development in Africa

Overtime, the performance of the manufacturing sector in SSA has not been impressive. The performance of manufacturing sector is captured by using manufacturing value-added (MVA) as percentage of gross domestic product (GDP). Figure 1 shows the evolution of MVA as a percentage of GDP over the years. As revealed in the figure, it is evident that MVA has mostly followed a downward trajectory, dropping from an average value of 16.71% in the 1981-1990 period to 10.27% between 2001 and 2021. Specifically, for the period 2001-2005, average

annual MVA (% of GDP) in SSA was 12.11%; it reduced to 10.19% between 2006 and 2010 and further dipped to 9.88% between 2011 and 2015. The poor performance of manufacturing in SSA has been attributed to many factors among which are lack of infrastructure-supporting facilities such as good road networks, and constant power supply (Rodrik, 2016; Bhorat, et al. 2019).

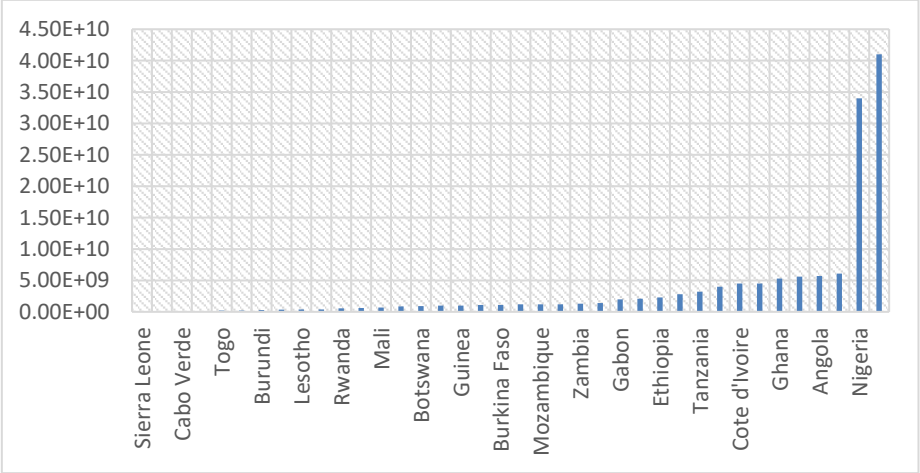
The poor performance of manufacturing in SSA has been attributed to many factors among which are lack of infrastructure-supporting facilities such as good road networks and constant power supply, as well as trade liberalisation and the globalisation drive of the Western world (Rodrik, 2016; Bhorat, et al. 2019; Kumeka, Raifu and Adeniyi, 2024). Figure 2 shows that, South Africa and Nigeria, the two largest economies in Africa, have the highest volume of MVA in SSA. However, the narrative changes when MVA is considered as a share of GDP as Eswatini becomes the SSA country with the highest average manufacturing share in GDP (see Figure 3). The manufacturing sectors in SSA are not the highest contributor to GDP as their share in GDP is lower than 20% in all the countries under consideration except Eswatini, whose manufacturing sector contributes more that 30% to the country's GDP. This indicates that manufacturing value added is relatively low in SSA and it explains the low manufacturing competitiveness of SSA countries as well as their high level of import-dependence. The low manufacturing value added in SSA has been attributed to financial constraints, bureaucratic bottlenecks, low domestic investment and poor power supply (Afolabi, 2022).

Figure 1: Manufacturing value added (% of GDP) for SSA



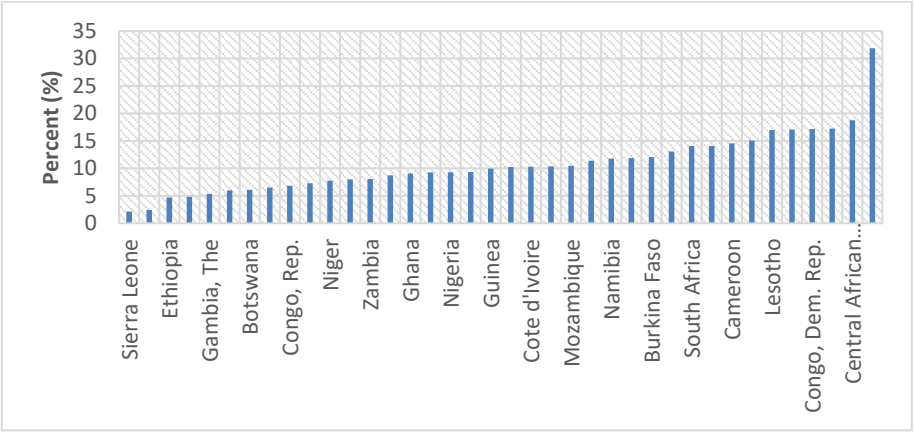
Source: Authors using data from World Development Indicators (2022).

Figure 2: Manufacturing Value-Added Across Selected sub-Sahara African Countries



Source: Authors using data from World Development Indicators (2022)

Figure 3: Share of Manufacturing Value-Added in the GDP of Selected sub-Sahara African Countries

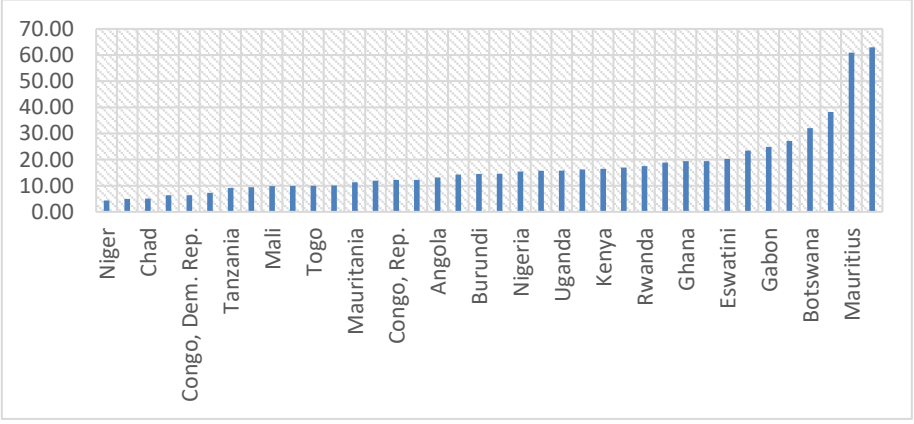


Source: Authors using data from World Development Indicators (2022)

With regard to infrastructural development, South Africa, Mauritius, Cabo Verde, Botswana and Namibia are the top five countries in SSA with the highest infrastructure index (see Figure 4). The scatterplot showing the bivariate relationship between infrastructure and MVA (in US dollar) as well as MVA (% of GDP) are in Figures 5 and 6. Many SSA countries are found in the low manufacturing and low infrastructure index region with only a few outliers. Nigeria, for instance, has a relatively high MVA but a low infrastructure development index while South Africa has both the highest MVA and infrastructure index in SSA (see Figure 5). Notably, Mauritius and Botswana also have a fairly good infrastructure index and a moderate MVA.

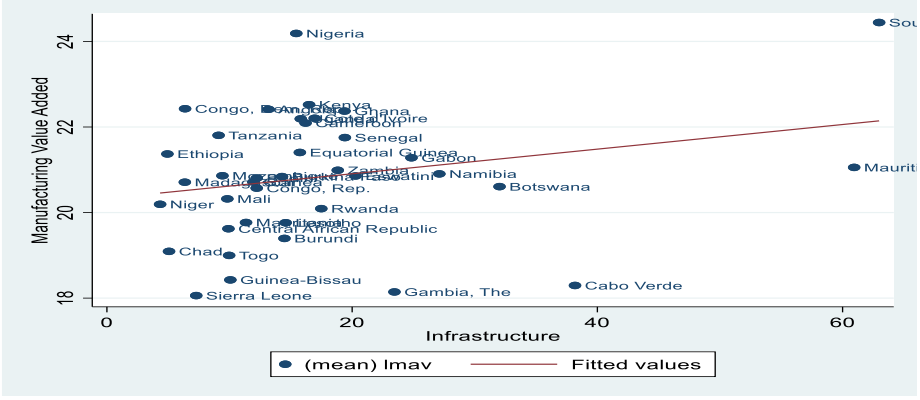
Similarly, in terms of the bivariate relationship between infrastructure and MVA (% of GDP), shown in Figure 6, many of the countries are clustered in the low regions of infrastructure index and MVA (% of GDP) region with a few outliers. Eswatini has the highest share of MVA in GDP among the sampled countries but a fairly weak infrastructural development while South Africa and Mauritius have relatively stronger infrastructural development but fairly low share of MVA in GDP. In sum, MVA and infrastructural development remain fairly weak in many SSA countries.

Figure 4: Infrastructure across selected sub-Sahara African Countries



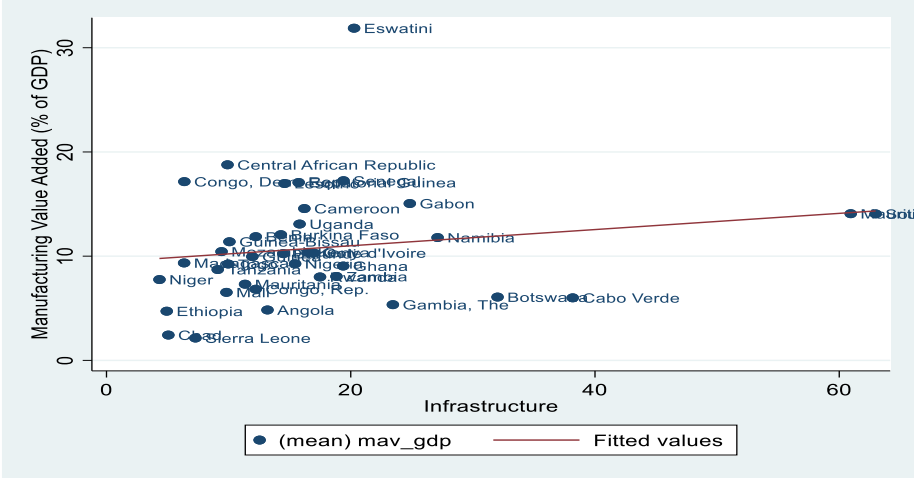
Source: Authors using data from Africa Infrastructure Development Index (2022)

Figure 5: Bivariate Relationship between Infrastructure and Manufacturing Value-Added (Billions of US Dollars) in Selected sub-Sahara African Countries



Source: Authors' computation

Figure 6: Bivariate Relationship between Infrastructure and Manufacturing Value-Added (% of GDP) in Selected sub-Sahara African Countries



Source: Authors' computation

3.0 Literature Review

Theoretically, public infrastructure has long been recognised as a critical factor that can stimulate productivity and aggregate output (Romer, 1986; Lucas, 1988; Barro and Sala-i-Martin, 1995). It can serve as a factor input and enhance the productivity of factors used in the production process; which can generate externalities (Wang, 2002; Mitra, Sharma and Veganzones-Varoudakis, 2016). However, on the empirical front, the large and growing literature on the productivity and output effects of infrastructure or, more broadly, public capital have produced diverse findings. A seminal contribution to the empirical debate is Aschauer (1989a, 1989b). Specifically, the study, which triggered an extensive research, examined the relationship between public capital and aggregate productivity in the US economy for the period 1949-1985 by assuming a simple production function specification in which output is produced by labour inputs plus private-sector and public sector capital. The findings reveal that the public sector capital or infrastructure has very strong positive effect on private-sector total factor productivity.

The empirical results of Aschauer (1989a, 1989b) have been widely queried on the basis of the implausibly high estimates (Munnell, 1992; Gramlich, 1994). Moreover, concerns have been raised with regards to the non-stationarity of the data used, endogeneity of public capital and the direction of causation (Aaron, 1990; Tatom, 1991; Holtz-Eakin, 1994; Baltagi and Pinnoi, 1995). Nonetheless, Aschauer's result was confirmed by Munnell (1990). More precisely, the author finds that a 1 percent increase in public capital stock would lead to a 0.34 percent increase in private sector output. This translates to a marginal productivity of public capital of roughly 60 percent given the size of the public capital stock and output, according to Munnell (1992).

Furthermore, Stephan (2003) explicitly addressing non-stationarity of the data, serial correlation, heteroscedasticity, and endogeneity of public capital corroborated the findings of Aschauer. Using data from the manufacturing sector of the 11 West German Federal States from 1970 to 1996, the study established that public capital is a significant input for production in the manufacturing sector and that differences in public capital endowment can explain long-term differences in productivity across the

German States. In contrast, Hulten and Schwab (1991), Tatom (1991), Evan and Karras (1994), and Holtz-Eakin (1994) do not find evidence that public infrastructure has a large positive and significant effect on output growth. Notably, Holtz-Eakin (1994) offers some explanation for the heterogeneity in results; documenting that when the ordinary least squares (OLS) regression method is applied, the estimated output elasticity of public capital is large but the use of the generalised least squares (GLS) method yields a near zero or even negative output elasticity of public capital. Sharma and Sehgal (2000), assuming a basic production function in Cobb-Douglas form, examined the effect of infrastructure on the Indian manufacturing sector. Their findings, obtained by applying the fully modified OLS (FMOLS) to data for India spanning 1994-2006, reveal that infrastructure has a strong positive effect on total factor productivity, output, and technical efficiency although its effect on labour productivity is significant but negligible.

There have been arguments about the adequacy of the production function framework given that it omits input prices and imposes restrictions on firms' technology and behaviour (Munnell, 1992). A suggested alternative to the production function approach is the estimation of a generalized cost function that incorporates public infrastructure as a fixed unpaid factor of production. In view of this, Nadiri and Mamuneas (1992), in their assessment of the role of public capital on cost structure and productivity performance using data on twelve (12) two-digit U.S manufacturing industries, adopt the cost-function approach and bifurcate public capital into public sector infrastructure and R&D capitals. Their empirical findings reveal that both types of capital have significant positive productive effects although their effects on the cost structure vary across industries. Also, Holtz-Eakin and Lovely (1995) follow a general equilibrium approach and lend credence to the notion of a positive impact of public capital on manufacturing variety proxied by the number of manufacturing establishments. Paul, Sahni and Biswal (2004), estimating a flexible cost function for 12 two-digit Canadian manufacturing industries, established that public infrastructure matters for the productivity of manufacturing industries and it is a substitute for private capital and labour in the Canadian manufacturing sector. In the same vein, employing a constant elasticity and substitution-translog cost model to determine the relationship between Canadian public infrastructure and private output, Brox and Fader (2005) find

the services of public capital enhance the productivity of private capital. Similarly, Goel (2002) estimate a cost function model for India's manufacturing sector using time series data spanning 1965-1966 and 1998-1999. The results indicate that infrastructure enhances manufacturing sector productivity and lowers costs in India. The empirical findings of Mitra, Sharma and Véganzones-Varoudakis (2016) from their assessment of the importance of infrastructure and information & communication technology (ICT) on total factor productivity (TFP) and technical efficiency (TE) of the Indian manufacturing sector using data from 1994-2010 indicate that infrastructure and ICT have a significant effect on the manufacturing productive performance, both in terms of total factor productivity (TFP) and technical efficiency. Deepening the scope of the debate, Wan and Zhang (2017) proposed an analytical framework to estimate the direct and indirect effects of infrastructure on the productivity of Chinese manufacturing firms. The study employs large-scale firm-level survey data to circumvent endogeneity. The authors document that both the direct and indirect effects of infrastructure on firm productivity in China are positive and significant.

For studies employing time series data and single-infrastructure indicator, especially energy infrastructure, empirical results are largely contradictory. Onwe and King (2020), estimating the autoregressive distributed lag (ARDL) model using data from 1981 to 2019, show that electricity consumption (supply) has a short-run positive impact and a long-run negative effect on manufacturing output in Nigeria. The empirical results of Ene et. al. (2022), using similar method, reveal that electricity supply has a negative and insignificant relationship with the manufacturing sector output in Nigeria but technology has a positive and significant short-run relationship with manufacturing sector output in Nigeria. On the contrary, Chinedum and Nnadi (2016) find no evidence to suggest that electricity supply has a positive and significant relationship with manufacturing sector performance in Nigeria. Again, Abokyi, Appiah-Konadu, Sikayena and Oteng-Abayie (2018) conclude that electricity consumption has a negative effect on manufacturing output in Ghana.

For studies that use panel data for Africa, the literature is growing but the bulk of the known previous studies did not explicitly addressed the possible bias to statistical inference that cross dependence may pose. In addition, the empirical evidence remains

largely inconclusive. For instance, utilizing the fixed effect model and data from 25 African economies, Mesagan and Bello (2018) found no evidence to suggest that infrastructure significantly impacts manufacturing value added – the study's proxy for industrial performance. Similarly, Anyanwu (2018) shows that accessibility to ICT technology and infrastructure proxied by mobile phone and fixed phone subscriptions has no significant effect on manufacturing value added development in Africa. In fact, the result obtained using disaggregated data for social infrastructure was mixed. Specifically, primary education showed an inverted U-shaped relationship with manufacturing value added; secondary education negatively and significantly affected MVA while tertiary education had a positive and significant effect on MVA in Africa.

From a micro perspective, Moyo (2013) examines the impact of power infrastructure on productivity in African manufacturing firms. The study finds that power infrastructure quality, measured using the number of hours per day without electricity and the percentage of output lost due to outages, negatively affects productivity in African manufacturing firms. Estimating a random effects model with data for 17 SSA countries for the period 2003 to 2018 Azolibe and Okonkwo (2020) show that electricity, transportation, and water supply and sanitation infrastructures have no significant effect on industrial sector productivity while telecommunication infrastructure stimulates industrial sector productivity in SSA. Raifu, Nnadozie and Adeniyi (2021), applying the system Generalized Method of Moments (sGMM) estimation technique to data from 24 African countries for the period 2003 to 2019, demonstrate that ICT infrastructure spurs structural transformation in Africa. Using a similar methodology, Osei (2022) find that infrastructure development exerts a positive and significant influence on industry sectors' growth using data from 29 SSA countries spanning 2000–2014 period. Nnyanzi et. al., (2022) evaluate the effects of infrastructure development, liberalization, and governance on manufacturing output in SSA. Accounting for cross-sectional dependence, the results suggest a positive and significant effect of infrastructure development on MVA. More precisely, transport infrastructure is shown to have the dominant effect on MVA while the effect of electricity access is strongly significant in rural areas rather than urban centres.

Overall, while the link between infrastructure development and manufacturing sector performance has been acknowledged in the literature across several contexts, there are findings which suggest that infrastructure, at worst, has a negative impact or, at best, has a positive or no impact on manufacturing sector performance. Notably, empirical research on the nexus between infrastructure and MVA in SSA is relatively sparse and findings are sketchy at best. Known studies employing panel data for SSA countries largely ignore the possibility that the presence of cross sectional dependence, heteroscedasticity, and autocorrelation could exist and lead to inefficient estimates plus bias standard errors. Taking these econometric issues into consideration in our estimation, this study, thus, re-examines the link between infrastructure and MVA in SSA.

4.0 Methodology

4.1 Theoretical Framework and Model Specification

The theoretical framework upon which this study relies on is the traditional Cobb-Douglas production function which shows that aggregate output is a function of capital, labour, and other factors usually captured by A. The Cobb-Douglass production function is often specified as follows:

$$Y = AL^{\alpha}K^{\beta} \quad (1)$$

where Y denotes aggregate output, L represents labour used for production, K is the capital employed in the course of producing aggregate output and A is the total factor productivity, also referred to as efficiency factors, which captures other factors that can affect aggregate output apart from labour and capital. α and β are the elasticities of labour and capital respectively.

Although equation (1) is used for aggregate output, it can be adopted or adapted to the sectors of the economy. In other words, it can be used for the disaggregated economy which could be the agricultural sector, industrial sector (manufacturing subsector) and services sector. In this study, equation 1 is adapted to the manufacturing subsector of the economy. Thus, equation (1) is re-specified as follows:

$$Y_i = A_i L_i^{\alpha} K_i^{\beta} \quad (2)$$

Where Y_i is the manufacturing subsector performance (output or value-added), L_i is the labour employed in producing manufacturing output, K_i is the capital used in the production of manufacturing output and A_i is the technical efficiency of manufacturing output. According to Nnyanzi, et al. (2022), the technical efficiency of the manufacturing sector captures other factors that can augment the manufacturing sector apart from labour and capital. Drawing from existing studies (Adamu and Dogan, 2017; Anyanwu, 2017; 2018; Azolibe and Okonkwo, 2020; Azolibe, 2021; Nnyanzi, et al., 2022), the technical efficiency (A_i) in this study captures other variables such as infrastructure (INFRA), GDP per capita (GDPPC), foreign direct investment (FDI), trade openness (TROPEN), exchange rate (EXTRATE) and governance (GOV). Thus, A_i is specified as follows:

$$A = (INFRA, GDPPC, FDI, TROPEN, EXTRATE, GOV) \quad (3)$$

By incorporating equation (3) into equation (2), we have equation (4) specified as follows:

$$Y_i = INFRA_i^{\chi} GDPPC_i^{\delta} FDI_i^{\eta} TROPEN_i^{\phi} EXTRATE_i^{\varphi} GOV_i^{\gamma} L_i^{\alpha} K_i^{\beta} \quad (4)$$

Since we are working with a panel data, equation 4 can be transformed as follows:

$$Y_{it} = INFRA_{it}^{\chi} GDPPC_{it}^{\delta} FDI_{it}^{\eta} TROPEN_{it}^{\phi} EXTRATE_{it}^{\varphi} GOV_{it}^{\gamma} L_{it}^{\alpha} K_{it}^{\beta} \quad (5)$$

By linearising, equation 5 can be transformed as:

$$\ln Y_{it} = \alpha_0 + \alpha_i \ln L_{it} + \beta_i \ln K_{it} + \chi_i \ln INFRA_{it} + \delta_i \ln GDPPC_{it} + \eta_i \ln FDI_{it} + \phi_i \ln TROPEN_{it} + \varphi_i \ln EXTRATE_{it} + \gamma_i GOV_{it} + \varepsilon_{it} \quad (6)$$

To estimate equation 6, we begin by using the fixed effect estimation method which accounts for individual country effect and year effect. Given this, equation (6) can be re-specified as follows:

$$\ln Y_{it} = \alpha_0 + \alpha_i \ln L_{it} + \beta_i \ln K_{it} + \chi_i \ln INFRA_{it} + \delta_i \ln GDPPC_{it} + \eta_i \ln FDI_{it} + \phi_i \ln TROPEN_{it} + \varphi_i \ln EXTRATE_{it} + \gamma_i GOV_{it} + v_i + \varepsilon_{it}$$

$$i = 1, ..., N(individual);\ t = 1, ..., T(Time) \quad (7)$$

However, the use of fixed effects (FE) estimation method for the implementation of equation (7) may violate some of the classical regression assumptions, especially serial correlation/ autocorrelation and heteroscedasticity as well as cross-sectional dependence which could bias the estimated parameters (Reed and Ye, 2011; Bai, Cho and Liao, 2021). Taking this into cognisance, two other panel estimation methods – Flexible Generalised Least Squares (FGLS) and Panel Corrected Standard Estimator (PCSE) are employed.

By taking the issues of autocorrelation, heteroscedasticity, and cross-sectional dependence into consideration during the estimation, Bai, et al. (2021) argue that Generalised Least Squares is more efficient than the Ordinary Least Squares (OLS) and FE estimation methods (see also, Hansen, 2007). Nonetheless, while the use of FGLS addressed the aforementioned issues, it has been argued that FGLS estimation method underestimates the standard error in finite sample (Beck and Katz, 1995; Reed and Ye, 2011; Bailey and Katz, 2011). Hence, it may not be suitable when the number of countries or cross-sectional units is greater than number of periods (time) as in the case of this study where the number of countries is 38 and the period is 17 years. Thus, we also apply the PCSE estimation method, proposed by Beck and Katz (1995), which modifies the FGLS estimation method by preserving the Prais-Winsten weighting of observations for autocorrelation and employs a sandwich type estimator that incorporates cross-sectional dependence when standard errors are computed (see Nnyanzi, et al. 2022).

While the issues of cross-sectional dependence, autocorrelation, and heteroscedasticity have been addressed by the FGLS and PCSE estimation methods, another common issue that can arise from panel data analyses is the endogeneity problem. For this study, there is the likelihood of simultaneity bias. While infrastructure can spur manufacturing sector performance, a booming manufacturing sector can also lead to demand for or development of new infrastructural facilities. Hence, such relationship between two variables may potentially bias the estimation results (Raifu, Nnadozie and Adeniyi, 2021). To overcome the problem of endogeneity, this study employs two-step difference Generalised Method of Moments (GMM) developed by Arellano and Bond (1991). It is a dynamic model which is

specified by modifying equation 6 to account for the lag of manufacturing output or value-added as follows.

$$\ln Y_{it} = \ln \lambda_i Y_{it-1} + \alpha_i \ln L_{it} + \beta_i \ln K_{it} + \chi_i \ln INFRA_{it} + \delta_i GDPPC_{it} + \eta_i \ln FDI_{it} + \phi_i \ln TROPEN_{it} + \varphi_i \ln EXTRATE_{it} + \gamma_i GOV_{it} + \varepsilon_{it} \quad (8)$$

All other variables remain as previously defined. However, it is important to elucidate on the lag of manufacturing value-added. As specified in equation (8), manufacturing value-added depends on its lag and other variables in the model. This suggests that the current level of manufacturing value-added depends on its lag and it implies that the manufacturing value-added occurs over time or persist over time. This means that a country or countries with a high level of manufacturing value-added in the past is/are likely to experience growth in manufacturing value-added in the future (Raifu, et al. 2021).

As previously stated, the inclusion of other variables is motivated by their use in the existing empirical literature. Existent studies by Adamu and Dogan (2017), Anyanwu (2017, 2018), Azolibe (2021) and Nnyanzi, et al. (2022) used variables such as labour, capital, GDP per capita, FDI, trade openness, exchange rate, and governance as drivers of manufacturing sector performance (see also Salisu, Gupta and Kim, 2022). In this study, capital is proxied by gross fixed capital formation (% of GDP), labour force denotes employment, GDP per capita is used to measure the level of economic development, foreign direct investment captures the presence of foreign investors in the economies of the selected SSA countries, trade openness measures the degree of openness of SSA economies to the rest of the world, exchange rate captures the condition of SSA economies while governance is employed to capture the nature of administration of governments and their institutions in SSA economies.

The governance index used in this study is constructed from six governance indicators which include control of corruption, government effectiveness, political stability and absence of violence, regulatory quality, rule of law and voice and accountability. Following Raifu, et al. (2021), the principal component analysis (PCA) is used to compute the governance index which is then normalised to range from 0 to 1, where 0 denotes poor governance and 1 represents good governance.

On a priori ground, it is expected that both capital and labour will have positive effects on MVA. Similarly, infrastructure is expected to influence MVA positively. A higher level of economic development has been linked with the greater MVA (Ajakaiye and Ncube, 2010). Hence, GDP per capita should have a positive effect on MVA. With regard to foreign direct investment (FDI), trade openness, exchange rate, and governance, their effect on MVA could be mixed – either positive or negative. In particular, FDI could have a positive effect on MVA if there are technological spillovers from foreign firms to domestic firms in the industry. However, FDI could result in a crowding out of domestic investment. Put differently, foreign firms may have a negative influence on domestic ones (Azolibe, 2021). In the case of governance, poor governance can serve as an impediment to the development of the manufacturing sector while good governance could spur the manufacturing sector. Thus, governance could have either a positive or negative effect on manufacturing performance (Nnyanzi, et al. 2022)

4.2 Data Sources

This study utilises data for 38 SSA countries to examine the effect of infrastructure on manufacturing sector performance in the region. The data covers the period from 2003 to 2020. The choice of the period is due to the availability of relevant data. The data sources include the African Development Bank, World Development Indicators (WDI) and World Governance Indicators (WGI). Specifically, data on infrastructure index is obtained from the Africa Infrastructure Development Index (AIDI). It is a composite index obtained from four (4) different composite indices of infrastructure variables - electricity, transport, ICT, and water and sanitation. Each composite index of a particular infrastructure variable is obtained from different proxies of that specific infrastructure variable. For example, transport composite index is computed from total paved roads (kilometre/10,000) inhabitants and the road network in kilometres (km). Electricity composite index is calculated from total electricity production of a given country and energy imported from abroad (both public and private energy generated). The index is measured in kilowatt-hours produced per inhabitant. ICT composite index comprises total phone subscriptions per 100 inhabitants (fixed-line telephone subscriptions as percentage of population and mobile cellular subscription as percentage of population), number of internet users per 100 inhabitants, and

international internet bandwidth (Mbps) while water and sanitation composite index is computed from improved water access as percentage of population with access and improved sanitation facilities as percentage of population with access.

Manufacturing value-added (million US$), manufacturing value-added expressed as a percentage of GDP (%), labour force (million of population), gross fixed capital formation expressed as a percentage of GDP (%), gross domestic product per capita (Million USD), foreign direct investment (Million USD), trade openness (%), and exchange rate (Naira per Dollar) are collected from World Development Indicators.
The six governance indicators – control of corruption, government effectiveness, political stability and absence of violence, regulatory quality, rule of law, and voice and accountability – used to compute a governance index are sourced from the WGI. All the variables used for estimation except governance index are naturally logged.

5.0 Empirical Findings

This section presents the results of effect of infrastructure development on manufacturing sector performance in the panel of 38 sub-Sahara African countries. A series of preliminary tests were conducted before the main model estimation and analysis. These preliminary estimations include descriptive statistics, correlation analysis, and cross-sectional dependence test for the baseline model. However, we only present the results of correlation analysis. The descriptive statistics and cross-sectional dependence test results are put in the appendix. Also presented in this section are the results of the Panel Fixed Effect, Feasible Generalised Least Squares (FGLS), Panel Corrected Standard Estimator (PCSE) and Two-step Difference Generalised Methods of Moment (GMM). Each of these estimation methods, particularly FGLS, PCSE and GMM are used to address a specific issue related to panel data analysis.

5.1 Results of Correlation Analysis

Table 1 presents the results of the pairwise correlation analysis. As shown in the table, infrastructure is positively correlated with MVA (in US$ and % of GDP) and the relationship is statistically significant at the 5% level. However, there are variances in the directions of relationship of other control variables with MVA (in US$ and % of GDP). While labour, GDP per capita, FDI, and governance index are all positively and

significantly correlated with MVA (US$), capital, trade openness and exchange rate are negatively correlated with MVA (US$). On the other hand, GDP per capita, trade openness, and governance index have significant positive correlation with MVA_GDP, the converse is the case for the correlation between MVA_GDP and variables like labour, capital, FDI and exchange rate. A cursory look at the correlation among the variables shows the absence of multicollinearity problem as the correlation coefficients are relatively low.

Table 1: Pairwise Correlation Analysis Results

	MVA	MVA_GDP	INFRA	L	K	GDPPC	FDI	TROPEN	EXTRATE	GOV
MVA	1									
MVA_GDP	0.075*	1								
INFRA	0.426*	0.143*	1							
L	0.620*	-0.114*	-0.088*	1						
K	-0.123*	-0.289*	-0.014	0.021	1					
GDPPC	0.211*	0.227*	0.583*	-0.154*	0.177*	1				
FDI	0.557*	-0.021	0.191*	0.486*	0.107*	0.097*	1			
TROPEN	-0.228*	0.128*	0.176*	-0.402*	0.391*	0.430*	-0.057	1		
EXTRATE	-0.115*	-0.119*	-0.207*	-0.047	-0.073	-0.211*	-0.087*	-0.130*	1	
GOV	0.174*	0.002	0.665*	-0.116*	0.009	0.272*	0.087*	0.061	-0.201*	1

* shows significance at the 0.05 level

Note: MVA, MVA_GDP, INFRA, L, K, GDPPC, FDI, TROPEN, EXTRATE and GOV represent manufacturing value added (US$), manufacturing value added (% of GDP), infrastructure index, labour, gross fixed capital formation (% of GDP), GDP per capita, foreign direct investment, trade openness, exchange rate and governance index respectively.

5.2 Panel Regression Estimation Results

The panel estimation on the impact of infrastructure on MVA (USD and % of GDP) is done in phases using four distinct estimation techniques – panel fixed effects, feasible generalized least square (FGLS), panel correlated standard error (PCSE), and two-step difference Generalised Method of Moments (GMM). These techniques are utilised for a comprehensive and robust analysis of the infrastructure-MVA nexus. The

fixed effect model accounts for country and year effects; the FGLS estimator is applied to account for heteroscedasticity (FGLS1 in Table 1) and autocorrelation (FGLS2 in Table 1); and the GMM estimator shows results of models that control and does not control for standard error. The first phase of the analysis is done by first estimating the baseline model (without control variables) and later the extended model (with control variables). This is to verify whether the impact of infrastructure on MVA depends on the estimator applied. The results of the estimations are presented in Tables 2 and 3.

The empirical findings from both the baseline and extended models show that infrastructure exerts a positive influence on MVA (USD) in SSA, irrespective of the estimation technique adopted. The magnitude of impact, however, differs across the different estimators and the estimates suggest that MVA does not respond sharply to changes in infrastructure. Specifically, a percentage change in infrastructure leads, on average, to about 0.1-0.5 percentage change in MVA. In addition, the estimates of infrastructure impact in the baseline model exceed those of the extended models, indicating that the impact of infrastructure on MVA declines slightly when control variables are taken into consideration. The statistical significance of the infrastructure estimates indicates that infrastructure is a driver of MVA in SSA. This result is plausible as the presence of infrastructure reduces operating costs, eases business activities, and promotes better business interactions between stakeholders (Ogunjimi and Amune, 2019; Aminu, Raifu and Oloyede, 2018). These ultimately extend to productivity as they have positive ripple effects on the value addition activities of manufacturers.

Studies in the extant literature corroborate our findings. For instance, Sharma and Sehgal (2010) found that infrastructure positively affects total factor productivity, output, and technical efficiency of manufacturing sector in India; Anyanwu (2017) showed that ICT has a positive influence on manufacturing sector development in North African countries. Orji, Worika and Umofia (2017), Effiom and Benjamin (2018) and Ogunjimi and Amune (2019) documented the positive economic impact of infrastructure for Nigeria while Paul, Sahni and Biswa (2004) had similar findings for Canada. However, our result is at variance with Abokyi, Appiah-Konadu, Sikayena

and Oteng-Abayie (2018), which reported that infrastructure (proxied by electricity consumption) has a negative effect on manufacturing sector output in Ghana.
To gain further insights into the role of selected control variable in the infrastructure-MVA nexus, we present the results of the effect of other control variables on MVA. The labour force coefficients suggest that labour force exert a significant positive impact on MVA such that MVA increases with more employment. This signals the importance of labour in the manufacturing production process and, perhaps, explains the reason many SSA manufacturing sectors are highly labour-intensive. On the other hand, the effect of gross fixed capital formation (a proxy of capital) on MVA is mixed as the fixed effects and GMM estimators show that it has MVA-enhancing effects while the FGLS and PCSE estimators show that it hurts MVA in SSA.

The narrative on the effect of GDP per capita on MVA is quite interesting as the results of all the estimators unanimously reveal that an increase in GDP per capita improves MVA in SSA, albeit to varying degrees. This implies that, apart from infrastructure, GDP per capita is indispensable to the improvement of MVA in SSA. Thus, efforts at improving GDP per capita would subsequently improve the value addition activities of the SSA manufacturing sectors and possibly increase the volume of manufacturing products of the region in the domestic and international market. This could lower the region's import-dependence and position it on the path of structural transformation.

The coefficients of exchange rate and governance are negative across various estimators, revealing that exchange rate movements and governance hurt MVA in SSA. However, foreign direct investment (FDI) and trade openness have ambiguous effects on MVA. While some estimators show that FDI and trade openness improve MVA, others suggest that they inhibit MVA. On the one hand, the negative effect of FDI and trade openness on MVA could imply that manufacturing firms in SSA cannot withstand the competition from their foreign counterparts both in the domestic and international markets. On the other hand, their positive effects on MVA reveal that they have great prospects in improving MVA in SSA.

In the GMM model, the lag of MVA was found to determine the present value of MVA because it has a positive and significant effect on the current level of MVA. This

implies that there is a persistence in the level of manufacturing sector development in SSA. In other words, it suggests that current level of manufacturing sector development is influenced by the past development in manufacturing sector. Hence, there is a high tendency that if SSA would continue to have improved manufacturing sector performance in the future if it can sustain the current level of the performance in the sector.

As regards the diagnostic test results, evidence shows that the number of instruments is not greater than the number of groups, ensuring this eliminates the issue of proliferation of instruments. Hence, we can submit that we use appropriate number of instrument and there is no problem of instruments proliferation during the estimations of GMM. This finding is corroborated by the results of Hansen's overidentification test and Sargan's overidentification test, respectively. Given the values of the estimates of the two tests, it is evident that there is no problem of instrument overidentification which suggest that the right instruments are used. Thus, the GMM estimates are reliable.

Table 2: Effect of Infrastructure on Manufacturing Value Added

	Fixed Effects		FGLS1		FGLS2		PCSE	
	MVA	**MVA**	**MVA**	**MVA**	**MVA**	**MVA**	**MVA**	**MVA**
INFRASTRUCTURE	0.377***	0.116***	0.480***	0.065***	0.384***	0.034	0.483***	0.172***
	(0.043)	(0.044)	(.022)	(0.026)	(0.040)	(0.029)	(0.054)	(0.048)
LABOUR		1.117***		1.035***		0.948***		0.858***
		(0.142)		(0.014)		(0.016)		(0.014)
GROSS FIXED CAPITAL FORMATION		0.041		-0.380***		-0.053***		-0.102***
		(0.028)		(0.032)		(0.019)		(0.033)
GDP PER CAPITA		0.790***		1.266***		1.079***		1.109***
		(0.076)		(0.022)		(0.033)		(0.020)
FDI		-0.014*		-0.038***		-0.003		-0.010
		(0.007)		(0.009)		(0.003)		(0.007)
TRADE OPENNESS		-0.154***		0.162***		-0.020		-0.060
		(0.041)		(0.040)		(0.025)		(0.040)
EXCHANGE RATE		-0.205***		-0.012		-0.029**		-0.003
		(0.037)		(0.007)		(0.011)		(0.008)
GOVERNANCE		-0.320**		-0.681***		-0.046		-0.134
		(0.133)		(0.078)		(0.079)		(0.107)
CONSTANT	19.649***	0.054	19.55***	-2.414***	19.872***	-0.745**	19.522***	0.355
	(0.098)	(2.220)	(0.057)	(0.306)	(0.114)	(0.361)	(0.116)	(0.318)
OBSERVATION	684	647	684	647	684	647	684	647
NO OF GROUPS	38	38	38	38	38	38	38	38
R-SQUARED	0.592	0.697					0.993	0.999

F-STATISTCS	50.61 (0.000)	53.74 (0.000)						
WALD TEST (Chi2)			468.26 (0.000)	17712.10 (0.000)	91.73 (0.000)	6462.23 (0.000)	79.92 (0.000)	12817.24 (0.000)
COUNTRY DUMMIES	YES	YES						
YEAR DUMMIES	YES	YES						

*Note: For the main results standard errors are in parenthesis. However, for F-Statistic and Wald Tests, the values in parenthesis are probability values. *** p<0.01, ** p<0.05, * p<0.1. MVA denotes manufacturing value added measured in USD. FGLS1 is Feasible Generalised Least Squares accounting for heteroskedasticity across panels while FGLS2 accounts for heteroskedasticity across panels and autocorrelation within panels. PCSE is the panel correlated standard error method accounting for first-order autocorrelation and using time-series method to estimate autocorrelation parameters.*

Table 3: Two-Step Difference GMM Regression results

	Without Controlling Standard Error		**Control for Standard Error**	
	MVA	**MVA**	**MVA**	**MVA**
LAGGED MANUFACTURING	0.668***	0.224***	0.668***	0.224*
	(0.072)	(0.048)	(0.151)	(0.125)
INFRASTRUCTURE	0.222***	0.142***	0.222**	0.142
	(0.040)	(0.031)	(0.093)	(0.091)
LABOUR		0.340***		0.340*
		(0.065)		(0.186)
GROSS FIXED CAPITAL FORMATION		0.033***		0.033
		(0.012)		(0.029)
GDP PER CAPITA		0.905***		0.905***
		(0.044)		(0.143)
FDI		0.000		0.000
		(0.001)		(0.005)
TRADE OPENNESS		-0.022**		-0.022
		(0.010)		(0.030)
EXCHANGE RATE		-0.066***		-0.066
		(0.025)		(0.068)
GOVERNANCE		-1.006***		-1.006**
		(0.176)		(0.434)
OBSERVATION	570	497	570	497
NO OF GROUPS	38	37	38	37
NO OF INSTRUMENTS	19	34	19	24
WALD TEST	1423.6	9729.67	437.15	1096.89
	(0.000)	(0.000)	(0.000)	(0.000)

AR(1)	-2.03	-1.36	-1.88	-1.29
	(0.042)	(0.173)	(0.060)	(0.198)
AR(2)	-1.15	1.07	-1.15	1.06
	(0.251)	(0.284)	(0.251)	(0.290)
SARGAN TEST OF OVERID	24.74	32.25	24.74	32.25
	(0.101)	(0.151)	(0.101)	(0.151)
HANSEN TEST OF OVERID	23.17	25.19	23.17	25.19
	(0.144)	(0.452)	(0.144)	(0.452)

**** p<0.01, ** p<0.05, * p<0.1.*

Note: AR(1) and AR(2) are the Arellano-Bond test for autocorrelation of the first-differenced residuals and second-differenced residuals respectively.

5.3 Robustness Checks

For robustness, an alternative measure of the dependent variable is considered – percentage share of manufacturing value added (MVA) in GDP (MVA_GDP). This is to confirm whether manufacturing productivity effect of infrastructure is sensitive to the choice of manufacturing sector performance variable employed. As was the case in the model with MV_USD as the dependent variable, the estimation was done in two phases using four estimation methods. Baseline and extended models were estimated and their results are presented in Tables 4 and 5. The coefficients of infrastructure in all the baseline models, except for the fixed effect model, show that infrastructure does not only positively influence MVA_GDP; it is also one of its key determinants in SSA. This implies that one of the key strategic steps needed to boost MVA in SSA is infrastructural development.

Given that the infrastructure index comprises electricity infrastructure, transport infrastructure, ICT infrastructure, and water and sanitation infrastructure; improvement in these components will translate to better contribution of the manufacturing sector to aggregate output. Constant power supply will reduce the cost of alternative power supply and ensure production continues undisturbed. This will raise manufacturing output and the manufacturing sector's contribution to GDP. Similarly, good transport networks will aid easy movement of raw materials from the suppliers to the factory as well as the movement of finished products to middlemen and consumers. The unparalleled access to raw materials induced by good transport networks will reduce operating cost and promote uninterrupted production process. ICT infrastructure is also crucial to ease organizational and marketing processes,

thereby boosting productivity level. Overall, infrastructural development is crucial for boosting the share of the manufacturing sector in GDP in the SSA region.

The narrative changed slightly in the extended models, where control variables are introduced into the infrastructure-MVA_GDP model. Apart from the reduction in magnitude of impact of infrastructure on MVA_GDP across the estimated models, except in the GMM models, the significance of infrastructure in influencing MVA_GDP became ambiguous. Specifically, while the PCSE and GMM models that did not control for standard error show significant positive impact of infrastructure on MVA_GDP, the FGLS models shows insignificant impact and the fixed effect model shows a significant negative impact. This signals the sensitivity of the impact of infrastructure on MVA_GDP to the manner of model specification and the MVA indicator considered. Nevertheless, the results are robust and give credence to the earlier finding on the positive and significant impact on infrastructure and MVA in SSA.

Table 4: Effect of Infrastructure on Manufacturing Value Added (% of GDP)

	Fixed Effects		FGLS1		FGLS2		PCSE	
	MVA_GDP	MVA_GDP	MVA_GDP	MVA_GDP	MVA_GDP	MVA_GDP	MVA_GDP	MVA_GDP
INFRASTRUCTURE	-0.078	-0.290***	0.184***	-0.000	0.062**	0.015	0.201***	0.184***
	(0.068)	(0.069)	(0.014)	(0.029)	(0.025)	(0.035)	(.064)	(0.055)
LABOUR		1.782***		0.046***		-0.004		-0.078***
		(0.221)		(0.015)		(0.018)		(0.014)
GROSS FIXED CAPITAL FORMATION		-0.047		-0.373***		-0.098***		-0.194***
		(0.043)		(0.039)		(0.029)		(0.046)
GDP PER CAPITA		-0.249**		0.165***		0.071*		0.059**
		(0.118)		(0.026)		(0.040)		(0.027)
FDI		-0.012		-0.032***		0.000		-0.004
		(0.011)		(0.010)		(0.004)		(0.007)
TRADE OPENNESS		-0.272***		0.112**		-0.029		-0.185***
		(0.065)		(0.047)		(0.036)		(0.070)
EXCHANGE RATE		0.137**		0.013*		-0.007		0.019***
		(0.058)		(0.007)		(0.013)		(0.006)
GOVERNANCE		-0.047		0.057		-0.003		0.182
		(0.208)		(0.086)		(0.103)		(0.116)
CONSTANT	2.381***	-21.108***	1.793***	1.611***	2.149***	2.277***	1.745***	3.780***
	(0.155)	(3.461)	(.04)	(0.334)	(0.070)	(0.426)	(0.174)	(0.454)
OBSERVATION	684	647	684	647	684	647	684	647
NO OF GROUPS	38	38	38	38	38	38	38	38
R-SQUARED	0.011	0.190					0.708	0.838

F-STATISTCS	0.38 (0.990)	5.48 (0.000)						
WALD TEST (Chi2)			166.43 (0.000)	227.24 (0.000)	6.06 (0.0138)	29.43 (0.000)	9.720 (0.0018)	257.86 (0.0000)
COUNTRY DUMMIES	YES	YES						
YEAR DUMMIES	YES	YES						

*Note: For the main results standard errors are in parenthesis. However, for F-Statistic and Wald Tests, the values in parenthesis are probability values. *** p<0.01, ** p<0.05, * p<0.1. MVA_GDP denotes manufacturing value added measured as percentage of GDP. FGLS1 and FGLS2 are Feasible Generalised Least Squares accounting for heteroskedasticity across panels and heteroskedasticity across panels and autocorrelation within panels respectively. PCSE is the panel correlated standard error method accounting for first-order autocorrelation and using time-series method to estimate autocorrelation parameters.*

Table 5: Two-Step Difference GMM Regression results

	Without Controlling Standard Error		**Control for Standard Error**	
	MVA_GDP	**MVA_GDP**	**MVA_GDP**	**MVA_GDP**
LAGGED MANUFACTURING	0.506***	0.278***	0.506***	0.278*
	(0.067)	(0.051)	(0.158)	(0.167)
INFRASTRUCTURE	0.071**	0.124**	0.071	0.124
	(0.031)	(0.062)	(0.063)	(0.166)
LABOUR		-0.868***		-0.868*
		(0.164)		(0.479)
GROSS FIXED CAPITAL FORMATION		0.110*		0.110
		(0.062)		(0.175)
GDP PER CAPITA		0.592***		0.592*
		(0.131)		(0.346)
FDI		0.032***		0.032***
		(0.007)		(0.010)
TRADE OPENNESS		-0.005		-0.005
		(0.054)		(0.135)
EXCHANGE RATE		0.093		0.093
		(0.066)		(0.144)
GOVERNANCE		-1.419***		-1.419
		(0.424)		(1.098)
OBSERVATION	380	334	380	334
NO OF GROUPS	38	37	38	37
NO OF INSTRUMENTS	24	32	24	32
WALD TEST	70.13	352.69	11.40	46.82
	(0.000)	(0.000)	(0.003)	(0.000)

AR(1)	-2.62	-2.02	-2.09	-1.42
	(0.009)	(0.044)	(0.037)	(0.155)
AR(2)	0.05	0.13	0.05	0.12
	(0.963)	(0.897)	(0.963)	(0.903)
SARGAN TEST OF OVERID	31.26	27.99	31.26	27.99
	(0.091)	(0.216)	(0.091)	(0.216)
HANSEN TEST OF OVERID	25.96	16.86	25.96	16.86
	(0.253)	(0.816)	(0.253)	(0.816)

**** p<0.01, ** p<0.05, * p<0.1.*

Note: AR(1) and AR(2) are the Arellano-Bond test for autocorrelation of the first-differenced residuals and second-differenced residuals respectively

6.0 Conclusion

The importance of the manufacturing sector as an engine of economic growth has been long recognised in the literature. Nonetheless, manufacturing value added and output in SSA remains low. Several factors militate against the growth and development of manufacturing sector. One of which is the level and quality of infrastructure. In principle, the availability of infrastructure facilities such as electricity, transportation, ICT, and water and sanitation can boost industrial and manufacturing performance. Yet, SSA continues to grapple with huge infrastructural deficits. In light of this, this study investigated the effect of infrastructure development on manufacturing value-added in SSA. A battery of estimation techniques was employed. Specifically, the fixed effects, FGLS, PCSE, and GMM estimators were adopted.

In general, our results show that infrastructure development positively and significantly influence MVA in SSA. This implies that infrastructure is indispensable to the performance of the manufacturing sector in the region. Thus, this study argues that in order to achieve the level of manufacturing sector development as canvassed for by international development agencies and as enshrined in Sustainable Development Goals (9), governments in SSA countries need to invest massively in the provision of state-of-the-art infrastructure facilities. Government efforts alone may not be enough to achieve the level of infrastructure development that would guarantee the growth and development of manufacturing sector and possible structural transformation of the economies in SSA. Thus, there is need to partner with the private sector and international development agencies to reduce the infrastructural gap.

Appendix
Descriptive Statistics

Variables	Obs	Mean	Std.Dev.	Min	Max	p1	p99	Skew.	Kurt.
MANUFACURING	684	3.66e+09	8.41e+09	5.10e+07	4.70e+10	6.30e+07	4.40e+10	3.989	18.32
MANUFACURING (% of GDP)	684	10.79	5.847	.233	35.215	.996	33.015	1.348	5.927
INFRASTRUCTURE	684	17.327	13.666	.369	79.635	2.362	77.5	2.391	9.9
LABOUR	684	8380000	1.15e+07	159892	6.20e+07	190676	5.50e+07	2.497	9.594
INVESTMENT	684	23.197	9.317	5.401	81.021	7.748	52.829	1.464	7.797
GDP PER CAPITA	684	2122.396	2614.821	258.629	16438.6	294.219	13421.6	2.425	9.637
FDI	684	7.52e+08	1.53e+09	-7.40e+09	1.00e+10	-1.90e+09	7.60e+09	1.962	15.015
TRADE OPENNESS	684	70.049	29.971	20.722	177.096	27.376	161.134	.952	3.589
EXCHANGE RATE	683	761.742	1412.3	.867	9829.93	1.405	8967.93	3.817	19.735
GOVERNANCE	684	.395	.188	0	1	.055	.953	.599	3.425

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ANNEXES: A GUIDE FOR AUTHORS

This guide contains instructions to authors on how to prepare their manuscripts before submission to the Editor. Any manuscript that is not consistent with this guide will be returned to the author(s) for compliance checks before resubmission.

A. THE LENGTH OF MANUSCRIPT

- Each manuscript should have a maximum of 35 pages.
- The article text should contain between 7000 and 9000 words, including all references and footnotes but excluding tables and charts.
- The text should be in MS Word, Times New Roman, with a 12-point font size, and single spacing.
- The text should be prepared using standard UK English.
- Unless an Author is reporting a historical event in a direct speech (which should be in the past tense), it is preferred that all references in an indirect speech should be in the present tense.

B. PRELIMINARY SECTIONS OF THE MANUSCRIPT

1. Title

- The title should be concise and informative.
- It should be stated on top of the first page and **not given** a separate page.

2. Author Information

- The name(s) of the author(s) should be written horizontally or row-wise below the title.
- The institutions of affiliation(s) of the author(s) should be footnoted with their corresponding e-mail addresses.

3. Abstract

- The abstract should be between 150 and 200 words and should not contain any undefined abbreviations or unspecified references.

4. Keywords

- The author(s) should provide 4 to 6 keywords that can be used for indexing purposes.

5. Classification Code (JEL)

- Appropriate numbers of JEL codes should be provided.

6. Acknowledgements/ Disclaimers

- Any acknowledgment or disclaimer should be presented as a footnote to the abstract.
- No reference should be given to a footnote in the main text (say, refer to footnote 3, etc.).

C. THE MAIN SECTIONS OF THE MANUSCRIPT

1. Sections

- Every manuscript should be organised into five main sections with the following headings: Introduction, Literature Review, Methodology, Empirical Findings, and Conclusion

2. Numbering of Sections/ Sub-Sections

- The sections should be numbered in Arabic numerals as in 1.0, 2.0, 3.0, etc.
- Where there is a need to create subsections, they should be labelled, for instance, under section 1 as 1.1, 1.2, 1.3, etc.
- Sub-sections should only be given headings and numbered if there are more than two paragraphs under at least two sub-sections in a particular section.

3. Numbering of Equations

- Equations should be numbered in Arabic numerals as in 1, 2, 3, etc. with the numbers placed on the right side of the equation.
- All equations should be typed using Microsoft Equation Editor or any other equation editor.
- All sets of mathematical derivations and econometric specifications involving more than 12 consecutive equations should be presented in the Appendices.
- All equations in the Appendices should be numbered in Arabic numerals attached to the letter A as in A1, A2, A3, etc. with the numbers placed on the right side of the equation.

4. Numbering and Heading of Tables

- Tables should be numbered using Arabic numerals as in Table 1: Z, Table 2: ZZ, Table 3: ZZZ, etc. (where Z, ZZ, ZZZ, etc. refer to the names of the tables).
- Only tables that are extensively discussed should be in the main text. All other tables should go to the Appendices.
- Any table that cannot fit into a page, irrespective of it being discussed extensively, should be taken to the Appendices.
- Tables in the Appendices should be numbered using Arabic numerals attached to the letter A as in Table A1: Z, Table A2: ZZ, Table A3: ZZZ, etc.

5. Numbering and Heading of Graphs/Charts

- Graphs should be numbered using Arabic numerals as in Chart 1: Y, Chart 2: YY, Chart 3: YYY, etc. (where Y, YY, YYY, etc. refer to the names of the charts).
- Only charts that are extensively discussed should be in the main text. All other charts should go to the Appendices.

- Charts in the Appendices should be numbered using Arabic numerals attached to the letter A, as in Chart A1: Y, Chart A2: YY, Chart A3: YYY, etc.

D. CONTENTS OF THE VARIOUS SECTIONS

1.0 Introduction

- Background
- Problem Statement and Research Questions/Hypotheses
- Objective(s)
- Relevance and Justification of the Study
- Outline of the Sections

2.0 Literature Review

- Conceptual Review and Stylised Facts
- Strands of the Theoretical Literature
- Strands of the Empirical Literature
- Gaps in the Literature and the Contributions of the Study

3.0 Methodology

- Review of Empirical Methodology
- Data and Definition of Variables
- Model Specification and Estimation Technique
- *A Priori* Expectations (Optional)

4.0 Empirical Findings

- Summary Statistics
- Analysis of Results
- Discussion of Results
- Summary of Findings

5.0 Conclusion

- Summary of the Study
- Policy Recommendations
- Assessment of Attainment of Study Objectives
- Suggestions for Future Research

References

- Author(s) should use APA citation and referencing style.

Appendices

- All equations, tables, and charts brought to the Appendices must be presented in the following format:
  - ✓ Appendix 1: Mathematical Derivations/ Econometric Specifications
  - ✓ Appendix 2: Tables
  - ✓ Appendix 3: Charts

- Tables in the Appendices should be numbered using Arabic numerals attached to the letter A as in Table A1: ZZ, Table A2: ZZ, Table A3: ZZZ, etc.
- Charts in the Appendices should be numbered using Arabic numerals attached to the letter A as in Chart A1: Y, Chart A2: YY, Chart A3: YYY, etc.

Research Ethics and Integrity

- To uphold the integrity of the research, the journal has requested that authors provide the data and estimation scripts utilized in the empirical section of the manuscript.