FINANCIAL FRICTIONS AND MONETARY POLICY SHOCKS IN SIERRA LEONE: DYNAMIC STOCHASTIC GENERAL EQUILIBRIUM MODEL

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Abstract

The paper investigates the role of financial frictions and monetary policy in Sierra Leone within the Bayesian Dynamic Stochastic General Equilibrium (DSGE) framework. This Bayesian DSGE model mirrors a small open economy characteristics with financial frictions acquainted with activities of heterogeneous agents in the households drawing. Using the Bayesian technique, the study employed quarterly macroeconomic data in Sierra Leone from 2007Q1 to 2021Q4. The findings from this study shows that financial friction shocks have transient converging effect on inflation and a negative impact on output gap in Sierra Leone. The monetary policy shock also has a negative but assuaging impact on output gap, demand shock has a transient negative impact on output growth while the productivity (supply) shock has a positive impact on output growth in Sierra Leone. The economics of the monetary policy shocks is that it assuages the contractionary impact on the economy albeit monetary policy alone cannot steer the economy to stimulate growth dynamics. Concerning the financial shocks, the economic intuition is that it is inimical to trust in the banking sector. These findings are evident that monetary authorities should boost financial system stability, thereby increasing confidence in the banking sector and revamp their efforts in stabilising prices with monetary policy geared at productivity at levels that are growth inducing and not inimical to stabilising inflation.

Keywords: Monetary policy, financial frictions, dynamic stochastic general equilibrium modeling, Bayesian estimation, Sierra Leone

JEL Classifications: C59, E32, E52, F41

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Introduction

In the modern economy, the financial sector plays a pivotal role as it links savers and lenders to infuse liquidity into productive sectors of the economy. Efficiency is promoted as transactional payments are steered and risk management thrives (Svenson, 2012). Hence**,** instabilities in the financial sector could result in macroeconomic disruptions as it propagates shocks to other parts of the economy. It has implications for the conduct of monetary policy, as it has been indicated that instability in the financial sector may be partly due to dynamics of monetary policy (Mishkin, 1996; Taylor, 2009).

Before Global Financial Crises (GFC), Dynamic Stochastic General Equilibrium (DSGE) models did not incorporate the role of financial frictions in exacerbating macroeconomic distortions and disruptions. In effect, the framework could not allow for interactions between monetary policy and financial stability, where excessively low interest gives rise to an escalation in non-performing loans that could dampen credit

[1] The views expressed in this article are those of the author(s) and do not necessarily represent the views of their affiliated institutions.

extensions. After the GFC, the paradigm has shifted in the policy realm of developed economies and emerging market economies. Few of these revelations portend that financial stability has to be put in the same pedestal as monetary policy conduct of low-income countries (Bondzie et al. 2014; Korze et al.2017). In this context, the case of Sierra Leone is of keen interest as it is one of the low-income countries that employs monetary targeting framework wherein high-powered money is transitioned to achieve price stability. Furthermore, the Bank of Sierra Leone has an explicit objective of maintaining financial sector stability, hence necessitating the inclusion of financial sector frictions in the model for monetary policy.

Moreover, since the structure of financial markets are yet to be fully developed and the capital markets are in their nascent stage(as is the case in most LICs), an assessment into the effects of financial frictions will provide new basis wherein vulnerabilities in the financial sector may dampen the effectiveness of monetary, whilst increasing the share of non-performing loans. For instance, the banking sector in Sierra Leone is challenged with asset quality issues as non-performing loans exceed the threshold of 10 percent. (BSL Prudential Guidelines (forthcoming)). Furthermore, the fixed income securities market is driven largely by the 1-year treasury -bills rate (reflecting high activity in this market) relative to the 91 &182-day market tenors are sometimes absent (BSL 2018, Financial Stability Report).

Monetary policy in Sierra Leone is enshrined within the monetary targeting wherein reserve money is the operating target and the ultimate target being price stability indicating low and stable inflation. Monetary policy has been implemented by BSL via the financial markets by injecting liquidity into the banking system when there are tightened liquidity conditions and mopping up or sterilizing of excess liquidity in the banking system to enable banks trade and meet customers' unexpected call on deposits. In this context, liquidity tightness and excess liquidity in the banking sector may be inimical to the entire system. These may result in monetary shocks that have been largely transitory emanating from the lingering effects of monetary policy dynamics over the review period.

The vintage 2007Q1 to 2021Q4 encapsulates policy shocks and the full operationalization of some policy levers akin to financial frictions impact, wherein monetary policy rates were increased and the non-performing loans rose dramatically from 23.38 per cent in March 2014 to 38.02 per cent in June 2014. Furthermore, over the period 2012 to 2013, private sector credit declined from 6.2 per cent to 4.7 per cent respectively (BSL Financial Soundness Indicators published by the IMF).

Financial frictions and monetary policies are key elements within the macro-economy of Sierra Leone. In this context, financial frictions erupt due to morally hazardous challenge through asymmetric information between lenders (banks and other financial institutions) and borrowers (customers and private sector participants).Consequently, friction emanating from this source introduces an endogenous countercyclical spread between savings and lending rates. For instance, average lending rate in the banking sector in 2018 was 21.35 percent relative to savings deposit rate of 2.90 percent. Financial frictions have affected the soundness and stability of the banking sector and the economy of Sierra Leone via the asset quality indicator. This study attempts to unravel the impact of these dynamics. Hence, this paper, attempts to fill the gap by gauging the monetary policy dynamics and financial frictions impact in the context of a Bayesian DSGE model for the economy of Sierra Leone. A DSGE model is a multivariate time-series model, which specifies the structural relationship between state variables and, control variables, and typically derived from economic theory.

This extension is spurred by the work of Balden et al. (2015) who suggest that structural macroeconomic models have the ability to improve the quality of quantitative macroeconomic policy analyses in Low Income Countries (LICs). The DSGE model in this paper employs the financial frictions framework of Curdia et al. (2010), which are enshrined contextually in small open economy models that are described in Justiniano et al. (2010). Beyond the methodology gap, this study attempts to unearth how selected key financial soundness indicators that have been correlated, and likely shocks that are propagated in the banking sector. Studies on dynamic stochastic general equilibrium model that enshrines financial frictions for a monetary targeting framework is hard to come by in Sierra Leone, hence the motivation for this current study to contribute in filling the gap in the literature.

The rest of the paper is structured as follows, section two analyses the conduct of monetary policy in Sierra Leone, section three depicts the stylised facts, section four then reviews the relevant literature. Subsequently, section five provides details of the estimation methodology and the prior parameter distributions, whilst section six then concludes the study.

Primer of Monetary Policy Formulation and Implementation in Sierra Leone

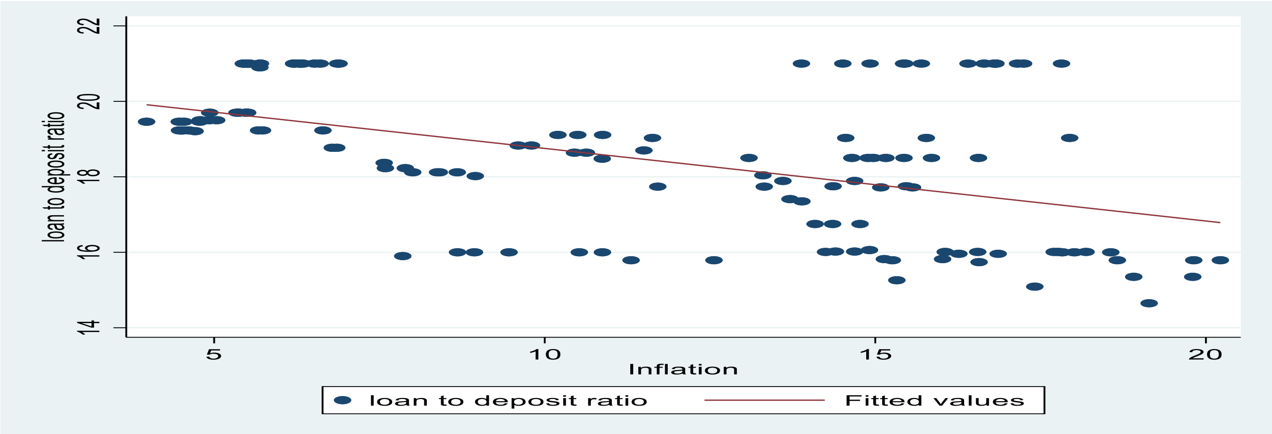
Monetary policy impulses propagate in the economy of Sierra Leone, as it is true for other developing economies. Despite empirical findings, persist concerning the nexus amongst macroeconomic variables, monetary policy has surely had immense impact over the period (since 2011). The Bank of Sierra Leone introduced Open Market Operation (OMO) as a bold step toward the adoption of market based monetary policy stance. Other market-based tools that came into operation include reserve requirements, discount window operations, forex sales and standing facility. It is deducible from the foregoing that Sierra Leone's financial sector, by virtue of some fundamental and structural reforms, has acquired enormous capacity and resilience in the use of indirect tools in achieving policy objectives. In this context, the Bank of Sierra Leone (BSL) introduced these market-based tools to gauge both the rate of interest and bank credit. The BSL is cognizant of the interest rate-money supply channel in the transmission mechanism for monetary policy impulses permeating into the entire economy. In a free-market economy, demand and supply forces stimulate the determination of prices and allocation of resources. Direct instruments (such as credit ceilings, sectorial credit allocation, interest rate controls) of monetary policy has evidently prompted financial repression. (IMF Report 2010). Hence, market based tools have been used by BSL ever since monetary policy rate was first set in March 2011.

Consequently, the Bank's monetary policy framework is monetary targeting focused on the growth of a chosen monetary aggregate. In the context, reserve money is the key operating target, whilst the nominal anchor or intermediate target is broad money. The monetary targeting framework is entrenched on the basis that in the long term, price growth influenced by money supply growth. In terms of the communication of the monetary policy stance is executed via a forward guidance (monetary policy statement) published by the Bank on its website reflective of a tight(hawkish) monetary stance or a loosened(dovish) monetary stance or a neutral stance depending on domestic and Global macroeconomic conditions at the time and how it feed-through to the economy.

Stylised Facts

This section elicits dynamics in monetary policy rate, inflation and other selected financial soundness indicators over the review period. This is needed to elicit key dynamics of monetary policy shocks and selected financial soundness indicators in Sierra Leone.

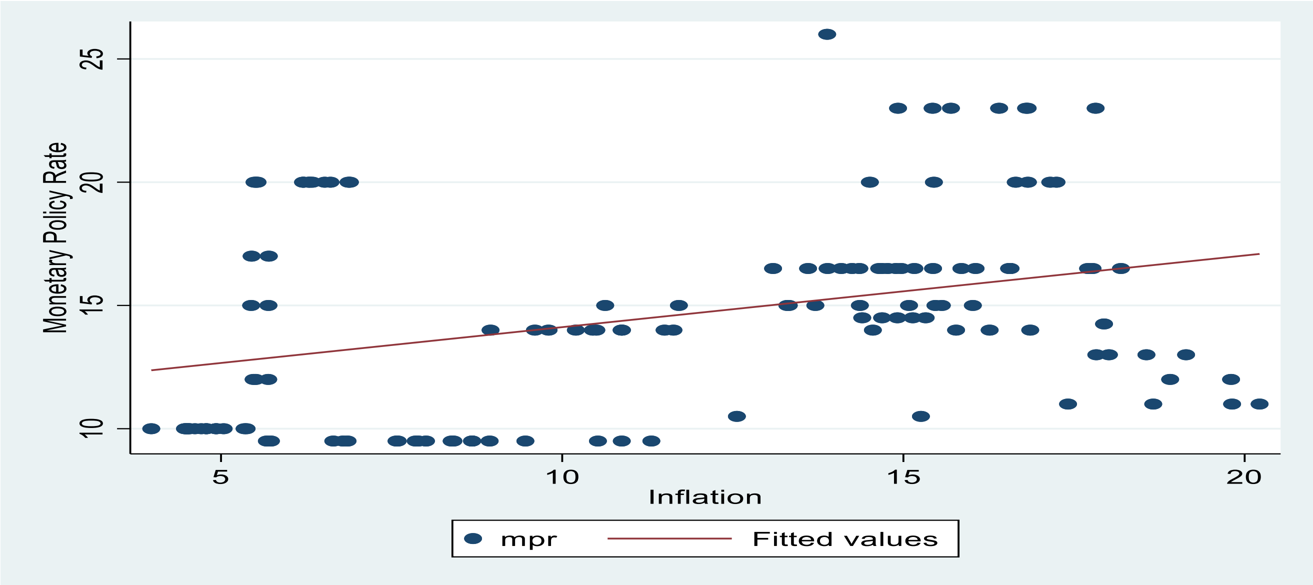
Figure 1a: Loan-to Deposit Ratio versus Inflation



Source: Bank of Sierra Leone, 2022

The scatter diagrams above indicate the relationship between loan to deposit ratio versus inflation over the period 2011 to 2021 on a monthly basis. The diagram reveals that that is an inverse relationship/correlation between loan to deposit ratio and inflation. This reflects that whilst loan-to-deposit ratio has been on the decline, inflation has risen over the period confirming that financial soundness has improved but price stability (low and stable inflation) has been on the upside.

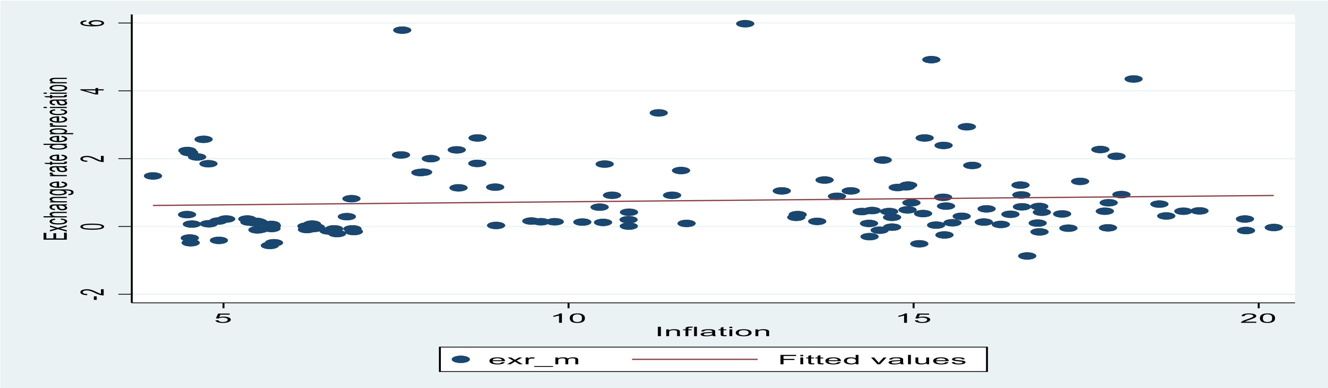
Figure 2b: Monetary policy Rate Versus Inflation



Source: Bank of Sierra Leone, 2022

Concerning the monetary policy rate and inflation rate, the correlation appears to be very weak reflective of the enfeebled transmission mechanism from monetary policy dynamics to inflation rate over the same coverage period. This speaks to the fact that monetary policy operations have to be steered preemptively to dampen inflationary pressures and strengthen banking sector stability.

Figure 1c: Exchange Rate Depreciation versus Inflation



Source: Bank of Sierra Leone. 2022

The correlation between exchange rate depreciation and inflation rate appears to be near perfectly elastic, reflecting that regardless of the inflation rate dynamics, the depreciation in the domestic currency (Leones) hovers around a relatively fixed interval. Taken in one breath, whilst monetary policy dynamics is weak in terms of transmission mechanism and cushion inflationary pressures, financial soundness has improved over the review period.

Literature Review

DSGE models embeds economic sectors in a coherent and interrelated entity and mirrors the economy as a system reflective of the collective decisions of rational individuals via a nest of variables that incorporate current and future periods. These individual decisions are then coordinated amongst economic agents in building a macroeconomic model entrenched on microeconomic foundations. The literature on DSGE incorporating financial frictions is replete with empirical studies. For instance, Palic (2018) explored the empirical evaluation of policy shock in DSGE model with financial frictions in Croatia over the period 2000 to 2013. The study reflects that the empirical impact of monetary policy shock adequately mirrors the effect of monetary policy shock in DSGE model with financial frictions.

Furthermore, Del Negro et al., (2008) estimated a DSGE model of USA with coverage from first quarter of 1964 to third quarter of 2008. Their research revealed that their model mimicked successfully the contraction of economic activity in 2008 and 2009 in the United States. Benchimol (2015) evaluated the dynamics of money and monetary policy influenced output and inflation in Israel over the previous decade. The methodology used was comparing two Keynesian DSGE models employing rolling window Bayesian estimations over ten years (2001-13). The first is a standard independent model (Gali, 2008) whilst the other is entrenched on interconnected household preferences between consumption and money (Benchimol & Fourcans, 2012). The study found out that response of output with respect to money stocks rose during the Dot-com, Intifada, and Subprime crises. Conventional Monetary policy implementation declined whilst unconventional mode increased in taming inflation during the course of subprime crisis. Furthermore, the impacts of money on output gyrations are mirrored as a better mimic of bank and debt risks. Through the influence of gauging of households 'money holdings, policy makers. By impacting and monitoring households' money holdings, policy makers can better their forecasts and boost crisis management via models assessing monetary aggregates. This translates to providing early warning signals to safeguard financial stability and bolster the efficacy of monetary policy.

Regarding Africa, previous research employing DSGE modelling is abounding. For example, Takyi et al., (2019) examined macroeconomic impacts of Fiscal Policy in Ghana by estimating a DSGE Model with Financial Exclusion. Their study used quarterly time series data from 1985Q1-2017Q4 to estimate the model's parameters using a Bayesian approach. The results show that a positive government spending shock has an expansionary effect on the consumption of financially excluded households but has a decreased effect on that of fully financially included ones. The study found that positive consumption and labor income tax shocks decrease the consumption of financially excluded households more than that of financially included ones. From a policy perspective, government spending is effective for increasing output, employment, and the consumption of financially excluded households, although it reduces that of financially included ones.

Younous (2017) employed an estimated a DSGE model for Bangladesh to evaluate the central bank reaction function and to analyse the policy shocks on inflation and output. The models have two stochastic shocks: productivity and the other of monetary policy. The sample period covers from 1991Q1 to 2014Q2. This model captures the behavior of the three key macroeconomic variables: GDP growth, inflation, and the policy rate. The Bayesian estimation method is used to get the posterior means based on priors and the likelihood function. The conditional variance decompositions, smoothed shocks show that the DSGE model captures the policy shocks from the data well. The main lesson is that the effective approach to controlling inflation is the management of monetary policy for Bangladesh. The monetary policy shock affects output in a positive fashion. Thus, monetary policy plays a significant role in macroeconomic stability in the country.

Benchimol et al., (2019) assessed the dynamics of central bank losses and monetary policy rules using a Bayesian DSGE model to gauge twelve monetary policy rules with vintage 1955 to 2017 and over three different sub-periods. The study found that when considering the central bank's loss functions, the estimates often show the superiority of Nominal Gross Domestic Product level (NGDP) targeting rules, yet Taylor-type rules results in almost identical effects. Nevertheless, the results put forward that numerous central bank empirical rules, be they NGDP or Taylor type, are more suitable to achieve the central bank's objectives for each type of period (stable, crisis, recovery). This study on monetary policy shocks and financial friction in Sierra Leone will draw out key insights on the effects of monetary shocks on and financial frictions in Sierra Leone, thereby providing an informed compendium for policy makers, central bankers on crafting policies to stimulate price stability whilst boosting financial system stability. Hence, this attempt to unravel these dynamics is quite useful and its implications for the monetary policy and financial stability realms cannot be overemphasised.

Motivated by these attractions, the contribution of this study to the empirical literature is four-pronged. Primarily, the paper delves into the impact of financial frictions and its pass-through to inflation and output. Secondly, the study unravels monetary policy shocks and its transmission mechanism to the output. Subsequently, the study then encapsulates a demand shock and its dynamics on inflation, interest rate and output. The study then gauges the dynamics of productivity shocks and its permeation to output. This findings from this study will unravels interesting insights as informed compendium to investors, policy-makers, market participants and academics as well on the potential impact of these shocks within the DSGE space and policies that may be crafted and implemented to safeguard financial stability and thrive monetary policy implementation. This is further by the fact that it serves as early warning signs for any untoward event in banking sector.

The Model

To gauge the role of financial frictions and monetary policy in Sierra Leone in a small open economy, this paper employs as its theoretical basis, the financial frictions model presented as an extension of the standard Keynesian model put forward by Stata DSGE Reference Manual (2017 page 42-46). The DSGE model embeds a system of equations retrieved from theoretical economics and hence has a straightforward interpretation of parameters. The model employed in this paper comprises of seven equations that mimic the behaviour of households, firms, external sector and the central bank as specified across the equations. Details of the financial frictions model are reported in the appendix. Equation 1 reflects Household optimisation eliciting the Euler equation which specifies output gap as a linear combination of future output gap (xt+1), nominal interest rate (rt), and a state variable (e_t) which mirrors changes in the natural level of output.

$$x_t = E_t x_{t+1} - (i_t - E_t \pi_{t+1} - g_t) \qquad (1)$$

Equation 2 illustrates a Phillips Curve engendered from optimisation by firms called the New Keynesian Phillips Curve (NKPC) based on the Calvo (1983) and Taylor (1980) staggered-contracts models (see Roberts, 1995). The equation lays down inflation (π_t) as a linear blend of future inflation (π_{t+1}) and the output gap (x_t). The parameter kappa (k) gauges how responsive inflation is to excess demand in the economy and should have a positive sign. The parameter β mirrors inflation expectations.

$$\pi_t = \beta E_t \pi_{t+1} + k x_t \qquad (2)$$

The central bank's monetary policy rule is presented in equation (3) which specifies interest rate as a linear mixture of inflation and a state variable (ut) that encapsulates movements in the interest rate that are not induced by inflation. The parameter A condenses the degree to which the central bank responds to gyrations in inflation. This equation can be thought of as being a specification of safe interest r_t

$$r_t = \mathsf{A} \pi_t + u_t \qquad (3)$$

The new element is equation (4), which specifies an equation for the market interest rate i_t that enters the output gap equation. The market interest rate i_t is a function of the safe interest rate and a state variable e_t. The new element

$$i_t = X r_t + e_t \qquad (4)$$

The market interest rate it is a function of the safe interest rate and a state variable e_t. The state variable e_t controls the interest rate spread and can be thought of as representing the state of the financial system. A large realisation of et represents a large interest rate spread, indicating financial distress. To complete the model, both state variables, gt, ut and et are modeled as first-order autoregressive processes in equations 4, 5 and 6, respectively.

$$g_{t+1} = p_g g_t + E_{t+1} \qquad (5)$$

$$U_{t+1} = P_u U_t + \in_{t+1} \qquad (6)$$

$$e_{t+1} = p_e e_t + n_{t+1} \qquad (7)$$

Where: ϵt+1 is the shock to the state variable ut (monetary policy shock); and εt+1 is the shock to the state variable gt (productivity shock). The state variable u_t is the deviation of rt from its equilibrium value of p_t.

The state variable g_t is also the deviation of x_t from its equilibrium value. To estimate the model specified above, a Bayesian Approach is employed using Stata 17.

The Data

The model makes use of quarterly data of macroeconomic variables for Sierra Leone. The sample spans the period 2007Q1 to 2021Q4, which includes all available quarterly output data for the Sierra Leone economy. Over this period, the main objective of the Bank of Sierra Leone has always been price stability and 2017 thereafter, financial stability came to the fore, and however, the official policy of the central bank was one of monetary aggregate targeting over the review period.

The analysis makes use of seven observed variables to estimate the model parameters. These include measures of the consumer price indices (inflation), output, monetary policy rate, general consumption growth rate, lending rate, traded weighted exchange rate. The measure for the permeation of financial frictions is the lending rate used as a proxy for the market interest rate. The measures for the foreign economy are computed from the trade weights of Sierra Leone's key trading partners (as used in the calculation of the real effective exchange rate). Those variables that have seasonal patterns are seasonally adjusted and all the variables are demeaned to provide implied steady-state values of zero.

Calibrations & Parameter Estimations

The Bayesian approach to the Dynamic Stochastic General Equilibrium model was employed to examine financial frictions and monetary shocks in a small open economy of Sierra Leone (see Table 1). While the objective was to estimate most of the parameters, it was necessary to calibrate the observed variables. The values for the calibrated parameters are retrieved from similar studies or the long run data properties. Bayesian analysis combines a likelihood model for the data with a specification of prior knowledge of the distribution of parameters to arrive at a posterior distribution for the parameters. Incorporation of prior information in DSGE models takes several forms.

First, the prior incorporates information that would be difficult or impossible to specify through the likelihood, broadening the amount of information that can be incorporated into the model. The likelihood is typically specified in terms of aggregate equations. However, some information about the parameters can be drawn from microeconomic evidence. This evidence can be incorporated into estimation via the prior. Second, the prior incorporates logical bounds on values that a parameter might take. Some parameters represent shares, for example a capital share of income or depreciation rate of capital, so that only the (0, 1) interval is an appropriate value for the parameter. A prior that takes on positive value in (0, 1) but has a zero probability elsewhere restricts the search to the desired region. Third, the prior can reflect information from theory, for instance, that a parameter should be positive or should lie above a critical threshold. All of this makes Bayesian estimation of DSGE models an appealing alternative to classical frequentist estimation. Priors are specified for the model parameter. The discount rate β must lie between 0 and 1, with common values in the range (0.90, 0.99) so that the annual steady-state real interest rate is three percent mirroring Galı (2008) and Ravenna et al. (2006) espousing small open economies. Following standard conventions, beta distributions are calibrated thus for parameters that fall between zero and one.

The price-adjustment parameter κ is usually thought to be small and positive. The autocorrelation parameters must lie in $(-1, 1)$ but are typically believed to be positive and closer to 1 than 0. The parameter $1/\psi$ must be greater than 1 for model stability and are inspired by Galı (2008) and Ravenna, et al. (2006); hence, ψ must be between 0 and 1, making the beta distribution a good distribution. The parameters of the beta prior for ψ place its center of mass on 1.5, a value commonly found in the theoretical literature. See Benchimol (2013) and Gali (2015). Priors were chosen to match the above theoretical considerations and amore of the economic realities in Sierra Leone. For the discount rate β, a *beta* distribution with shape parameters (95, 5) is used. These shape parameters place the prior mean at 0.95 and place most of the prior mass in the region between 0.9 and 1. For the price-adjustment parameter κ, a beta distribution with shape parameters (30, 70) is used. These shape parameters place the prior mean at 0.3 and place most of the prior mass in the region between 0.2 and 0.4. For the Taylor rule parameter ψ, a *beta* distribution with shape parameters (0.3, 0.7) is used reflecting (30,70). These shape parameters place the prior mean at 0.7, so that its inverse is 1.4, a common near value of 1.5 for this parameter in the literature.

For the autoregressive parameters, a *beta* distribution with shape parameters *theta*- (80, 20), *rhou*-(50, 50), *rhog*-(75, 25), *rhoes*-(50, 50), *rhor*-(70, 30), *rhop*-(30, 70), *rhosp*-(50, 50) are used as this is reflective for a small open economy of Sierra Leone. This place the prior mean of each state variable's autoregressive parameter at around 0.8, reflecting a prior belief that the state variables show a fairly high degree of persistence. The model is then blocked for *phi* and *theta* as these were the structural parameters that were such that their priors mimicked their posterior relatively well. Hence, reflecting the need to block those parameters that behaved well and gauge the evolution of the other parameters accordingly.

Table 1: Bayesian Header Output

MCMC Sample Size=10,000	Mean and Intervals		
		Burn-in= 2500	
Variable	Mean	Equal Tailed (95% Confidence)	
Rhor	0.946033	0.931816	0.9606171
Psi	0.644629	0.51231	0.7403634
Theta	0.722902	0.623609	0.8157524
Rhop	0.134815	0.090919	0.1875474
Beta	0.943864	0.873149	0.9851201
Kappa	0.40298	0.319706	0.5112937
Phi	0.302258	0.220591	0.3992317
Rhou	0.434733	0.373533	0.4981548
Rhog	0.956978	0.942369	0.9699382
Rhoes	0.53822	0.427157	0.6404195
Rhosp	0.597516	0.496486	0.6891855
sd(e.u)	1.482184	1.30753	1.657632
sd(e.g)	1.434421	1.324851	1.541869
sd(e.es)	3.470878	2.694844	4.562448
sd(e.sp)	1.588321	1.168736	2.133699

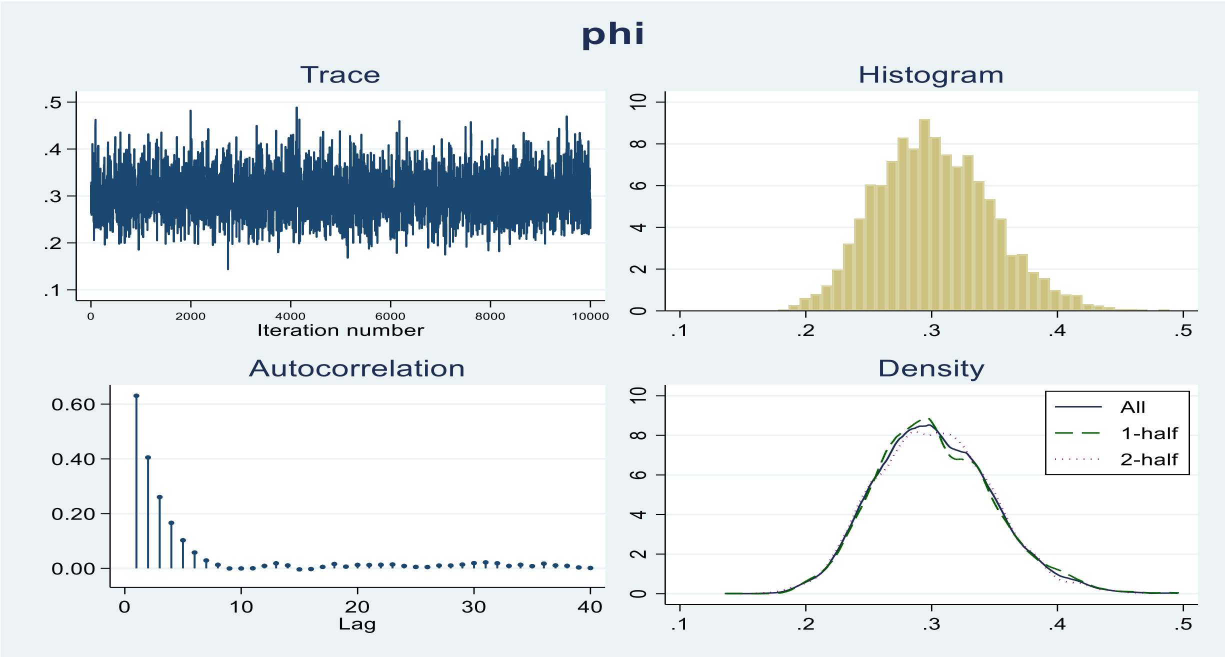
Source: Author's estimation based on dataset, 2022

Header output repeats the prior specification indicates that a DSGE model is fitted. The Markov Chain Monte Carlo (MCMC) acceptance rate is 0.4033, with efficiencies ranging from 0.1 per cent to 23 per cent. An acceptance rate of somewhat 40 per cent is typical for these models. Efficiency is linked to the autocorrelation of the MCMC draws, with higher efficiency indicating lower autocorrelation. Turning to parameter estimates, the posterior mean for (*beta*) is 0.94, close to the prior mean of 0.95. The posterior mean for (kappa reflecting the slope of the Phillips curve) is 0.40, about halfway between the prior mean of 0.3 and the maximum likelihood estimate of 0.08 is somewhat flatter. The coefficient on inflation in the interest rate equation is 0.64 and indicates that the central bank increases interest rates less than one for one in response to movements in inflation. The autoregressive parameters for the state variables are positive, with the state variable g showing autocorrelation (*rhog*) of 0.95 and the state variable *u* showing autocorrelation (*rhou*) of 0.43. This means that overall, many 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 (*beta*), (*theta*), and (*kappa*) are mainly driven by the prior.

Bayesian DSGE version 1 without the block option convergence

Plots are used to visually assess the Markov chain Monte Carlo (MCMC) samples chain: convergence and efficiency. To avoid undue complexities, visual diagnostic (of *phi*) is used to explore MCMC convergence. The trace plot should not exhibit any time trend and should have constant mean and variance. These properties can be inspected in the trace plot in the top left. The density of the chain should not vary over the duration of the MCMC sample. Constancy of the distribution can be assessed in the 1-half and 2-half density plots in the bottom right; if these plots differ dramatically, then the chain has not converged.

Figure 2: Visual diagnostics of phi



Source: Author's estimation based on dataset, 2022

The trace plot of phi shows reasonably good mixing, and the autocorrelations decay at a moderate pace. The density plot shows that the first- and second-half densities are similar to the density of the full MCMC sample. Densities that differ substantially in their first and second half can indicate non-convergence.

Efficiency summaries

Efficiency and mixing are terms used to describe how quickly the MCMC chain traverses the posterior domain. A chain that mixes well has high efficiency, low autocorrelation, and traverses the posterior quickly. A chain that mixes poorly has low efficiency and traverses the posterior slowly, exhibiting high autocorrelation in the MCMC chain. A chain that is less efficient requires more MCMC iterations to obtain the same information as a more efficient chain. Efficiency can also be assessed numerically. For our autoregressive model, the trace plot shows no time trend and appears to have constant mean and variance. The 1-half and 2-half density plots overlap with each other and with the full chain density. These features are indicators that the chain has converged. The autocorrelation of the chain dies out quickly, indicating that the chain has acceptable efficiency.

Table 2: Efficiency summaries

Variable	ESS	Corr.time	Efficiency
rhor	14.29	699.65	0.0014
psi	12.82	780.28	0.0013
theta	1709.87	5.85	0.1710
rhop	30.85	324.13	0.0031
beta	21.28	469.89	0.0021
kappa	17.62	567.68	0.0018
phi	2309.98	4.33	0.2309
rhou	26.26	380.84	0.0026
rhog	41.86	238.91	0.0042
rhoes	27.36	365.46	0.0027
rhosp	75.6	132.28	0.0076
sd(e.u)	20.82	480.21	0.0021
sd(e.g)	69.09	144.73	0.0069
sd(e.es)	1747	5.72	0.1747
sd(e.sp)	531.91	18.8	0.0532

MCMC sample size=10,000. Efficiency: min=0.001292, avg=0.04437, max=0.2309
Source: Author's estimation based on dataset, 2022

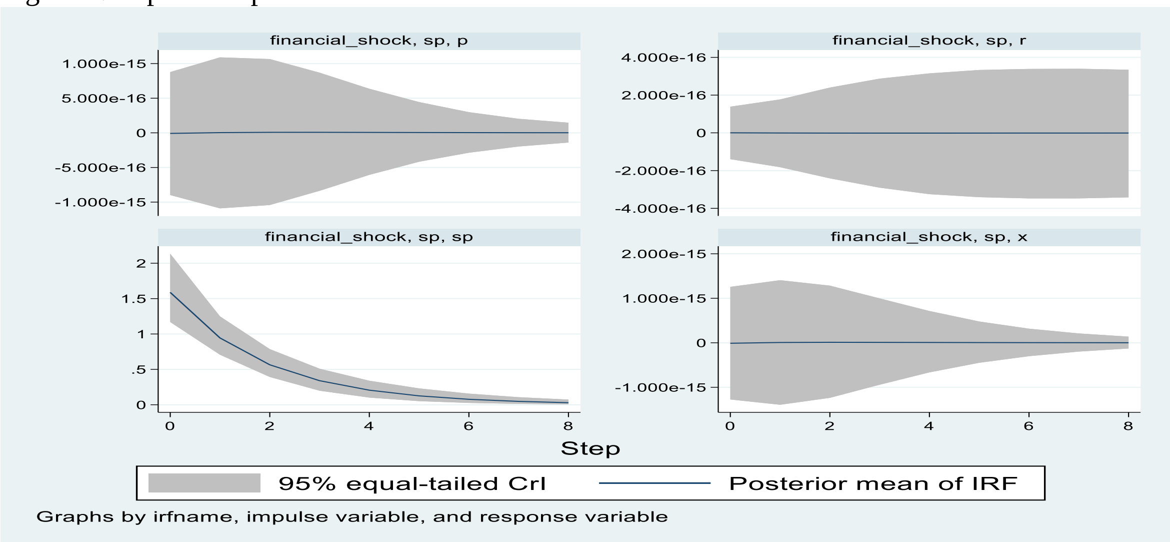
Blocking improves efficiency at the cost of longer run time. In Table 2, we see that efficiency has improved overall, with the minimum rising to 23.09 per cent from 0.1 per cent compared with the estimation without blocking. Effective sample sizes have improved. In particular, the effective sample size for the price-adjustment parameter (*kappa*) has also improved to 17.62. The effective sample size for the discount factor (*beta*) is somewhat low relative to the other parameters, which indicates that blocking may improve sampling efficiency.

Impulse response shocks that follow a financial policy shock

This section dives into Impulse Response Functions (IRFs) which show the effects of shocks on the adjustment path of the key variables of interest. IRFs are useful in assessing how shocks to economic variables reverberate through a system. The dynamic response in each of the variables follows the financial shock or perturbation reflected by innovations that tends to infinity to non-performing loans due to the winding of lending spread, illustrated in figure 3. To augment and guide the empirical exercise, the target variables are further redefined such that responses of the output gap (x), inflation (p), interest rate (r), and the state variable (u) to a shock to u are plotting accordingly. The steps are in the units of time that were used for estimation, so each step is one quarter, so that four steps are one year after the shock. Eight steps are computed and plotted by default. A rise in financial shock leads to a convergence (just after step two) of inflation (and largely converges at step eight) as interest rate diverges (just after step two before largely diverging at step eight) and the output gap also converges indicating a contractionary effect. The bottom-left panel shows the evolution of the state variable *sp* itself; it rises on a shock and then falls monotonically (from step two onwards) back to its steady state.

All three endogenous variables return smoothly to their steady-state values over time, as the effect of the shock dissipates. Along with point estimates, 95 per cent equal-tailed credible intervals are shown. The point estimates interesting but the credible intervals are somewhat narrower than the confidence intervals because of fairly tight priors used. The economic intuition behind this dynamics is that a financial shock dampens confidence in the banking sector and impedes the drive of the banks to lend to the customers that will in turn stimulate economic activity and contribute to economic growth in Sierra Leone.

Figure 3: Impulse response of a financial shock

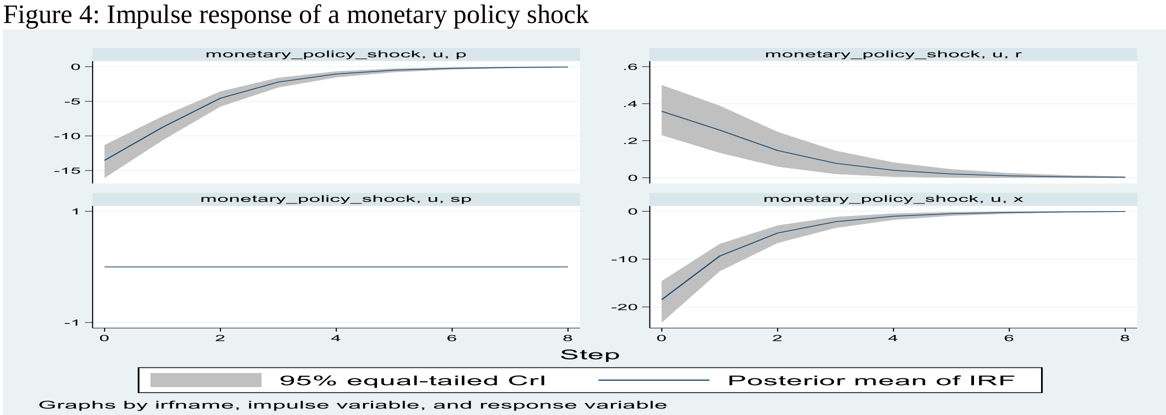


Source: Authors computations from dataset, 2022

Impulse response shocks that follow a monetary policy shock

Impulse response shocks that follow a Monetary Policy Shock embeds visualised responses of the output gap *x*, inflation *p*, interest rate *r*, and the state variable *u* to a shock to *u* as shown in 'Figure 4'. The steps follow the units of time that were used for estimation, indicating that one-step is one quarter. Eight steps are computed and plotted by default. A rise in the monetary shock (from period four then stabilises at period 8) follows a negative path, and leads to a rise in interest rate up to a magnitude of 0.4 before returning to its steady state from step six to eight as is shown in the top-right panel of figure 4. This impulse response shock of monetary policy permeates to assuage the contraction in output growth from 20 per cent onto near zero growth trajectory from steps four on to eight. Along with point estimates, 95 per cent equal-tailed credible intervals are shown. The point estimates are comparable. However, the credible intervals are somewhat narrower than the confidence intervals because of fairly tight priors used. Each panel displays the response of one model variable to the impulse.

Figure 4: Impulse response of a monetary policy shock



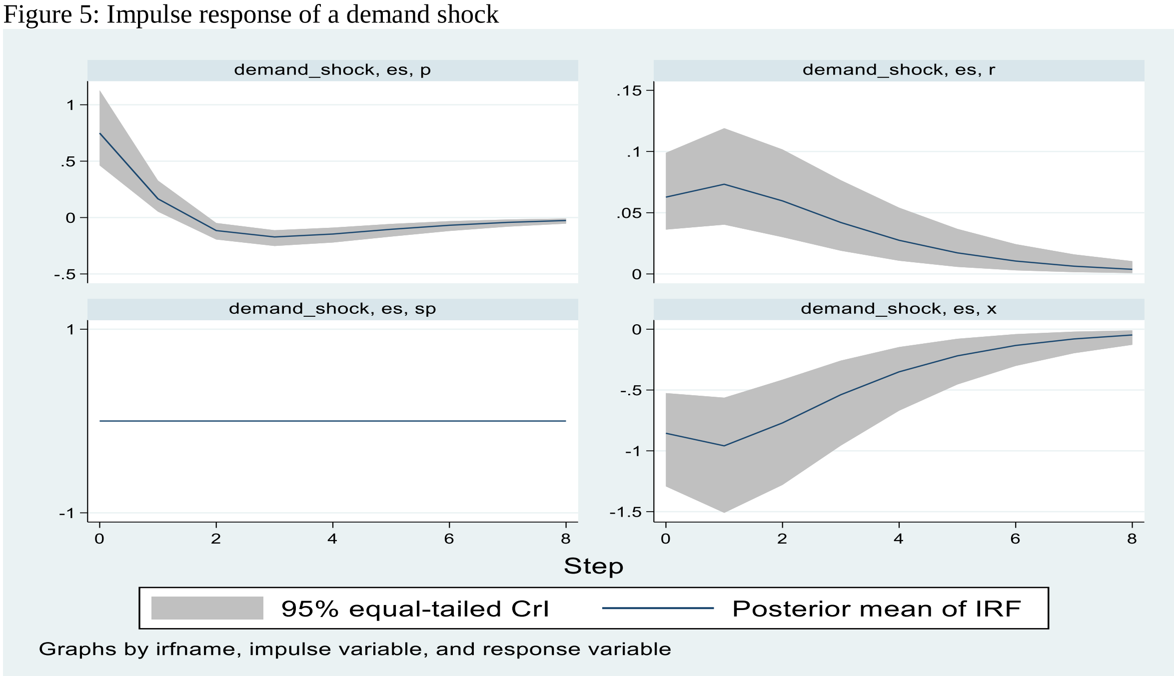
Source: Authors computations from dataset, 2022

The economics of the monetary policy impulse impulses is that it attenuates the contractionary impact of the economy. However, a key point must be made that it also follows that monetary policy alone cannot push the economy to unleash growth potentials of the economy of Sierra Leone.

Impulse response shocks that follow a demand policy shock

The illustrations are the responses of the output gap x, inflation p, interest rate r, and the state variable u to a demand policy shock to u. ideally, the steps are in the time units employed for estimation, specifically one-step is one quarter. Eight steps are computed and plotted. The impact of a demand shock on monetary policy rate shows that the rate first increases to about 0.25 units before moving to its steady state (after step 6). In turn, interest rate initially increases (just before step 2) before flattening out and returning to steady state equilibrium. These dynamics then feeds through to soften the negative impact of output gap (across the various steps). All three endogenous variables revert smoothly to their steady-state values over time, as the effect of the shock dissipates. Along with point estimates, 95 per cent equal-tailed credible intervals are shown. The point estimates are quite interesting however, the credible intervals are somewhat narrower than the confidence intervals because of fairly tight priors used. The economic implication of this dynamics is that the demand shock ultimately translates to stimulate supply and this prompts a positive impact or stimulate economic potential on the economic growth trajectory.

Figure 5: Impulse response of a demand shock

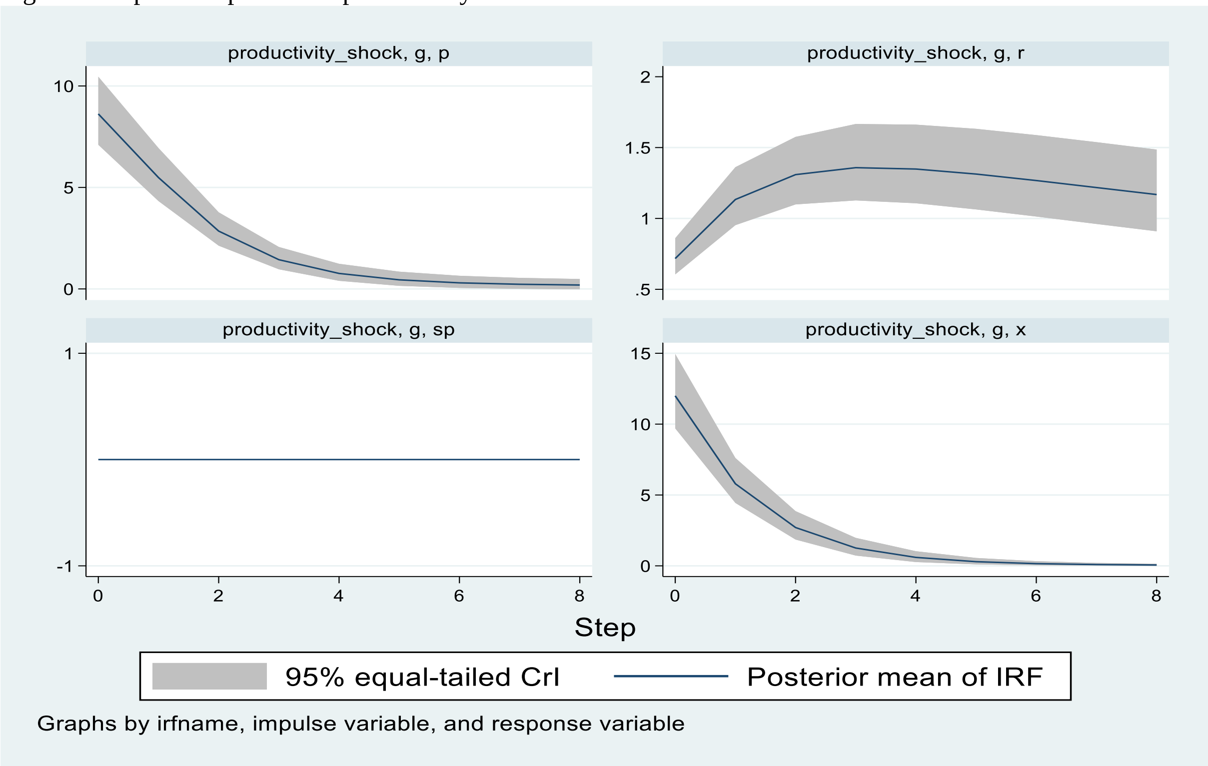


Source: Authors' computations from dataset, 2022

Impulse response shocks that follow a productivity shock

Figure 6 shows the responses of the output gap *x*, inflation *p*, interest rate *r*, and the state variable *u* to a productivity shock to *u*. ideally, the steps are in the time units employed for estimation, specifically one-step is one quarter. Eight steps are computed and plotted. The productivity shock elicits an increase in monetary policy rate with mean just about eight (8) units before flattening just around step four (4) and returning back to steady state (from step six to eight). This in turns permeates to rise in interest rate peaking (just around step four) before returning to steady state equilibrium. This dynamics of events then increases the output gap just around 13 units thereafter; it declines and reverts to steady state (from steps 4 onto 8). All three endogenous variables revert smoothly to their steady-state values over time, as the effect of the shock dissipates. Along with point estimates, 95 per cent equal-tailed credible intervals are shown. The point estimates are quite interesting however, the credible intervals are somewhat narrower than the confidence intervals because of fairly tight priors used. The economics of this is that a productivity shock feeds through in the chain of these events and catalyses a rise in output gap(positive) thereby contributing to economic growth in Sierra Leone.

Figure 3: Impulse response to a productivity shock



Source: Authors' computations from dataset, 2022

Conclusion

The banking sector affects several other sectors of the economy, where imperfections could prompt macroeconomic vulnerabilities. Following the recent GFC, research on business cycles in many developed and developing countries has prompted embedding financial frictions in structural macroeconomic models. The paper attempts to estimate a small open economy DSGE model with financial frictions (proxied by the lending rate reflective of the market interest rate) and monetary shocks with Sierra Leone data as the primary objective in the context of Bayesian Dynamic Stochastic General Equilibrium Approach. Financial frictions are included with the aid of framework proposed by Curdia et al. (2010), employing heterogeneous agents for savers and borrowers.

Guiding the empirical exercise, model parameters were initially calibrated according to the Bayesian technique based on expert knowledge, understanding of the Sierra Leone economy, sound economic theory, country experiences with relatively the same economic structure as Sierra Leone and value judgment. Next, the model was taken to the data and the following results came out. Firstly, the results reveal that the data is informative as the posterior mean is different from the prior mean. Second, the habit persistence parameter was high and data driven. This implied the high persistence of households' consumption behavior in Sierra Leone. Third, in the Phillip curve equation, the Calvo price stickiness was established for Sierra Leone, which indicated that firms in Sierra Leone tend to change their prices frequently.

Furthermore, the results indicate that that the key posterior parameter estimates are largely consistent with the values that are found in the general literature and the dynamics of the model suggest that monetary authorities a rise in monetary policy shock dampens inflation and interest rate and this declines output. This brings to the fore the need for the monetary authority to be proactive and stand ready to tinker with the monetary policy rate in order to achieve price stability (low and stable inflation).

Analysis of the impulse response functions of financial shock revealed that the economic intuition behind these dynamics is that a financial shock dampens confidence in the banking sector and impedes the drive of the banks to on lend to the private sector participants (customers) that will in turn stimulate economic activity and contribute to economic growth in Sierra Leone. Furthermore, the economics of the monetary policy impulse impulses is that it attenuates the contractionary impact of the economy. However, a key point must be made that it also follows monetary policy alone cannot push the economy to unleash growth potentials of the economy of Sierra Leone.

Additionally, the results pointed out that the economic implication of this dynamics (demand shock) is that the demand shock ultimately translates to stimulate supply and this prompts a positive impact or stimulate economic potential on the economic growth trajectory.
The economics of the productivity (supply) shock is that a productivity shock feeds through in the chain of these events and catalyzes a rise in output gap (positive) thereby contributing to economic growth in Sierra Leone.

In view of the above conclusion, the following key points are made:

- The estimated small open economy model is a snapshot of the characteristics of the Sierra Leone economy embedding financial frictions and monetary policy shocks. However, the absence of the fiscal reaction function may not completely reflect the structure of the Sierra Leone economy. In this regard, studies encapsulating the modelling of the key fiscal variables within the Sierra Leone economy may be pursued for future studies.
- The direction of future studies may also focus on the need to use alternative priors to reflect the changes in the structure and fundamentals of the economy.
- Other filtering and modelling transformation techniques could also be directed in further studies.

The major policy implication emanating from the study is that prudent financial policies (for example, accretion of banks capital through the increase in minimum paid up capital has the proclivity to boost confidence in the banking sector and thwart financial frictions that elicit diffidence in the banking space.

Furthermore, potent monetary policies should be directed at largely price stability (low and stable inflation) rather than more of stabilization of output. This may be conducted with a cocktail of conventional and unconventional monetary policy measures. The expected net effect of operationalising these policies is thriving of private sector growth and this permeates to contribute to economic growth and development in Sierra Leone.

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Conflicts of Interest

The author declares no conflict of interest regarding the publication of this paper.

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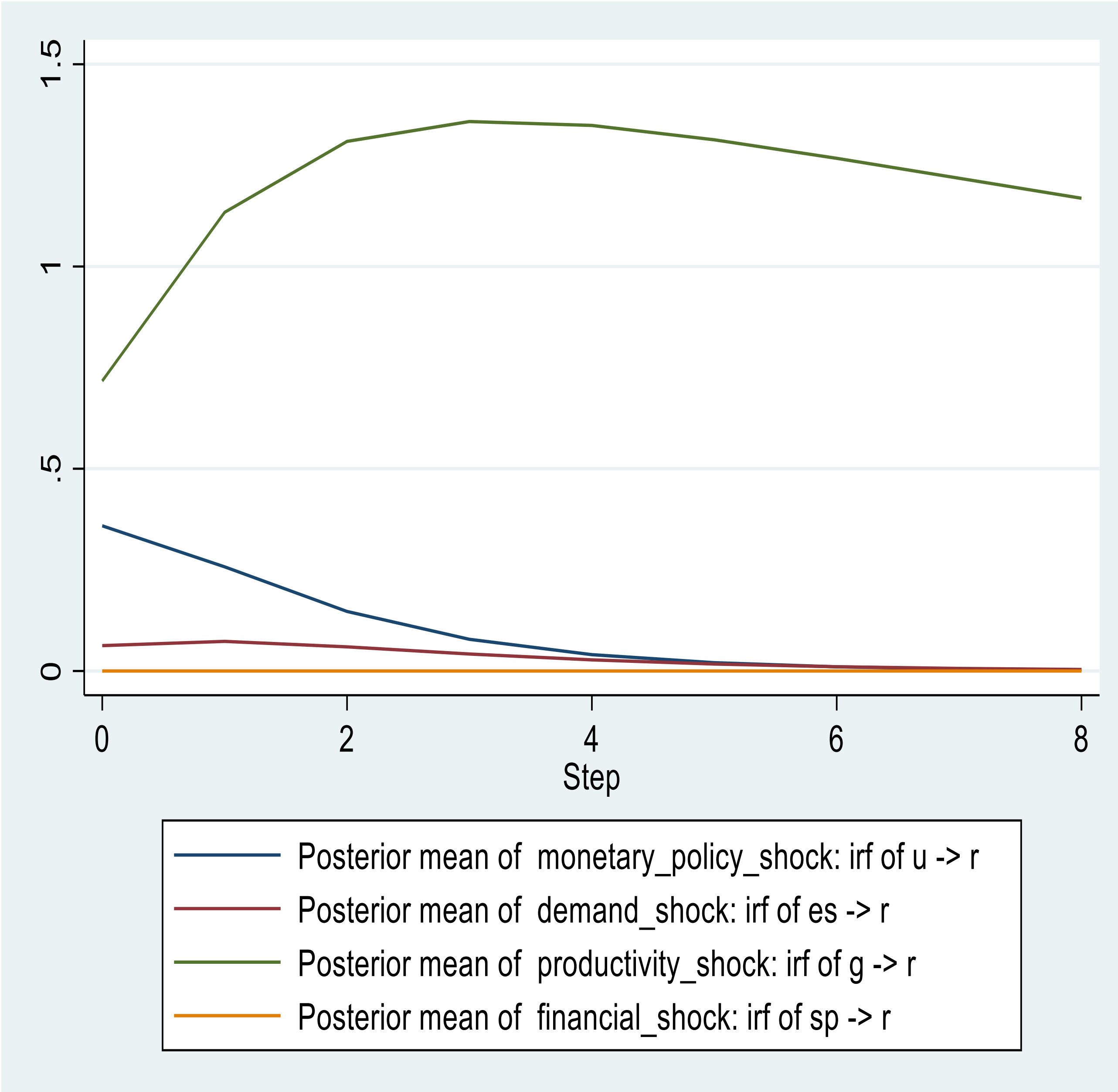
Appendix 1: Posterior perturbations from all shocks



Source: Authors' computations from Sierra Leone dataset, 2022

Appendix 2

```
Bayesian linear DSGE model                          MCMC iterations  =     12,500
Random-walk Metropolis–Hastings sampling            Burn-in          =      2,500
                                                    MCMC sample size =     10,000
Sample: 2011q1 thru 2018q3                          Number of obs    =         31
                                                    Acceptance rate  =      .4033
                                                    Efficiency:  min =    .001282
                                                                 avg =     .04437
Log marginal-likelihood =  -446.6196                             max =      .2309
```

	Mean	Std. dev.	MCSE	Median	Equal-tailed [95% cred.	interval]
rhor	.9460334	.0081155	.002147	.9451552	.9318159	.9606171
psi	.644629	.0661473	.018477	.6616471	.5123095	.7403634
theta	.7229022	.0496381	.0012	.7246148	.623609	.8157524
rhop	.1348151	.0243665	.004387	.1325962	.0909187	.1875474
beta	.9438643	.0292218	.006334	.9508728	.8731493	.9851201
kappa	.4029803	.0496488	.011829	.3979958	.3197061	.5112937
phi	.3022576	.0460666	.000959	.2995159	.2205914	.3992317
rhou	.4347327	.0320785	.00626	.4343439	.3735334	.4981548
rhog	.9569784	.0070404	.001088	.9570826	.9423691	.9699382
rhoes	.5382197	.0553567	.010582	.5403408	.4271566	.6404195
rhosp	.5975164	.049154	.005653	.598676	.4964857	.6891855
sd(e.u)	1.482184	.0932594	.020437	1.485047	1.30753	1.657632
sd(e.g)	1.434421	.0541387	.006513	1.434623	1.324851	1.541869
sd(e.es)	3.470878	.4768876	.01141	3.416099	2.694844	4.562448
sd(e.sp)	1.588321	.2497319	.010828	1.566581	1.168736	2.133699

Source: Authors' computations from Sierra Leone dataset, 2022