PSL Quarterly Review

vol. 73 n. 293 (June 2020)

Perspectives

Monetary policy responses to exogenous perturbations: The case of a small open economy (2007-2018)

CHRISTOPHER E.S. WARBURTON and EMERSON ABRAHAM JACKSON*

Abstract:

While autonomous central banks in large open economies are usually predisposed to use monetary rules to target inflation, output, and long-term interest rates, central banks in small open economies face peculiar challenges in their attempts to attain and maintain liquidity, stable prices and full employment. This paper investigates the effects of monetary policy in the case of Sierra Leone, assuming that information for rule-based monetary policy is insufficient and imprecise. We use the Bayesian model to evaluate primitive (*priors*)*, posterior enhancements and responses of key variables to exogenous perturbations based on information from 2007 to 2018. We find that the effects of disturbances that are associated with crude oil prices have a more persistent effect on national output than the dominant monetary instrument* (*T-Bills*)*. The response of monetary policy to exogenous perturbations is generally weak and less persistent. Granger-causality tests reveal that internal conditions make it less likely for the central bank to robustly react to external shocks.*

Warburton: East Stroudsburg University (PA, USA),
email: cwarburton@esu.edu
Jackson: Bank of Sierra Leone,
email: ejackson@bsl.gov.sl

How to cite this article:
Warburton C.E.S., Jackson E.A. (2020), "Monetary policy responses to exogenous perturbations: The case of a small open economy (2007-2018)", *PSL Quarterly Review*, 73 (293): 181-201
DOI: https://doi.org/10.13133/2037-3643_73.293_5

JEL codes:
E42, E 47, E50, E52

Keywords:
cointegration, Bayesian VARS, inflation, impulse response, money supply, oil shocks

Journal homepage:
http: //www.pslquarterlyreview.info

While autonomous central banks in large open economies are usually predisposed to use monetary rules to target inflation, output, and long-term interest rate, central banks in small open economies – economies that do not significantly affect the volume of global trade and prices in global markets – face peculiar challenges in their attempts to attain and maintain liquidity, stable prices and full employment. These challenges are usually the result of lack of autonomy, information deficiencies, and exogenous shocks. This paper investigates the effects of monetary policy when exogenous shocks are presumed to be overwhelming for a small open economy, Sierra Leone, and information for rule-based monetary policy is assumed to be insufficient and imprecise. We use the Bayesian model to evaluate primitive (*priors*), posterior enhancements and responses of key variables to exogenous perturbations based on information from 2007 to 2018. Further, unlike other studies, this paper compares the results

* Views expressed in this work are those of the authors and do not reflect any of the named institutions to which they are associated.

of frequentist (parameter-oriented) models to Bayesian models to find out if abnormalities can be detected in the responses of monetary and nonmonetary variables to exogenous shocks.

Beyond parameter estimates, we find, inter alia, that the effects of disturbances that are associated with crude oil prices have a more persistent effect on national output than the dominant monetary instrument (T-Bills). We note that the response of monetary policy to exogenous perturbations is generally weak and less persistent. The preferred methodology of this paper includes vector autoregression (VAR), with due consideration of the evolution of VARs and some of the prominent disagreements over VARs that have been expressed in the literature.

In section 1, we discuss the structure of the Sierra Leonean economy to provide background information of the policy challenges. The models and data that have been used as the empirical foundation for the findings of the paper are discussed in section 2. The models address the underlying monetary policy issues confronting the small open economy with a broader objective of evaluating the comparative performance of different models and their ramifications for future empirical analysis. We should note that the frequentist-probabilistic dichotomy has influenced this approach.

The variables of choice and their operationalizations are also discussed in the section. Like the US, and absent any liquidity trap, T-Bills – the short-term monetary instrument of monetary policy in the small open economy – is expected to play a much more dominant role in the small open economy. The short-term instruments are used to target monetary policy objectives. Evidently, reserve requirements tend to have residual monetary policy considerations in large and small economies; more so, in small open economies with a much more refractory private sector that drives liquidity or the lack thereof. Accordingly, in this paper, reserve requirements have been considered for evaluation in addition to national output and crude oil prices when a small open economy is not energy independent and is adversely susceptible to the vagaries of global oil price shocks that can be inflationary. In these types of economies energy availability also drives resource allocation and productive capacity. The findings and conclusions of the paper, which are supported by appendices, are provided at the end of the paper in section 3.

1. The structure of the Sierra Leonean economy

Monetary policy choices and outcomes are contingent on the structure of the Sierra Leonean economy and exogenous disturbances. The Sierra Leonean economy is historically rigid and largely configured by adverse historical circumstances from which the country has not successfully extricated itself (Jackson, 2018; Tamuke et al., 2018). Several countries that were once colonized by European powers became traditional sources of raw materials and consumers of manufactured goods from abroad. In effect, the colonial relationship and geographic conditions shaped the primordial patterns of international trade and the comparative advantages that were associated with production and technological capacities.

However, the geographic dichotomy and natural human capabilities have inadequately explained the economic relationships between the countries of the North and South, and the inability of some countries to grow and be prosperous. For too long, some countries that invested wisely and developed stable and superior systems of democratic governments were able to take advantage of dynamic comparative advantage and product cycles to diversify their economies and extricate themselves from the yolk of neo-colonialism. Superior policy choices have enabled countries to benefit from the dynamic pattern of the global economy. For example, some East

Asian countries that were once colonized adopted export-led growth (ELG) policies and political stability to espouse phenomenal levels of transition and economic growth.

Sierra Leone has neither been able to extricate itself from the colonial paradigm (since the 1960s) nor transition from such a paradigm into a manufacturing or flourishing service-oriented economy in an age of technological innovation (Jackson et al., 2019a). The investment in human capital has abysmally accompanied corruption and episodic internecine warfare over natural resources/resource curse (Jackson, 2017; Jackson, 2016; Jones, 2014). The horrendous spectacle of political and economic deterioration has portended unsavory prospects for the macro-economy. In the steady state of an agrarian economy and bourgeoning political democracy, belatedly encouraged by external intervention, the economy can best be characterized as a small open economy that cannot successfully withstand overpowering external global shocks. Accordingly, the external economic circumstances generate macroeconomic consequences that challenge notions of routine (conventional) macroeconomic policies that are designed to attain stabilization objectives.

Data on productive capacities, resource allocation, and consumption or distribution of final goods and services for the country – provided in table 1 – are revealing indicators of structural weaknesses. Though mining and quarrying show intriguing and rather large volatility, agriculture continues to be the main source of employment and economic activity. The International Monetary Fund (IMF, 2019) finds that agriculture employs more than half of the country's formal and informal workforce and accounts for about half of its GDP. A 2014 Labour Force Survey indicates that nearly 60 percent of employed individuals aged 15 to 64 works in agricultural self-employed sector (IMF, 2019, p. 21). In reality, of the productive sectors, only agriculture, services, and finance and real estate record positive growth from 2013 to 2017.

Resource allocation is extensively inefficient. Access to financial capital, land, and energy is a challenging proposition for production and growth (UNCDF, 2018). Forests and electricity continue to be major sources of energy. Wood and charcoal (agents of environmental degradation) constitute a whopping 80 percent of the sources of energy. Petroleum imports are equally significant with detrimental economic effects for the small open economy. Imports of petroleum, which constitute about 13 percent of the energy supply of the country, create foreign exchange risk exposures and depletion of reserves. Indeed, energy shocks can be destabilizing for small open economies. The paucity of energy supply creates distribution problems that impinge on productive capacity or potential. It is estimated that demand for energy will soar from 105 megawatts in 2018 to 360 megawatts in 2018 (IMF, 2019, p. 117). The Enterprise survey reveals that inadequate finance, energy inadequacy, and inaccessibility to land pose serious problems for SMEs (see table 1). Inaccessibility of land for the utilization of judicious economic activities is based on the prevailing land tenure system, which can be attributed to the dominance of colonial rule that divided the country's administrative governance into two parts – namely, "Protectorate and the Crown Colony" (Jackson, 2018).

The banking sector has not been a very reliable source of finance for the small businesses due to crowding out of the private sector by the influence of the dominant risk-free T-Bill market, which is dominated by the government appetite to access comparative low interest loans (Jackson and Jabbie, 2020; Jabbie and Jackson, forthcoming). Invariably, about 33 percent of small firms rely on finance by non-depository institutions. It is estimated that only about 8 percent of small businesses might receive loans from depository institutions; about 58 percent of large firms may not receive loans from depository institutions (World Bank, 2017, p. 28), implying that there must be a robust and significant financial shadow economy that cannot be

regulated by monetary policy (Jackson, 2020; Jackson and Jabbie, 2020; Jackson et al., 2019b). More so, it is not implicit that the large businesses without access to depository institutions will be able to get credit from shadowy non-depository institutions.

Table 1 – *Productive capacity* (*growth rate, percent*)

Categories	**2013**	**2014**	**2015**	**2016**	**2017**
Agriculture	4.6	0.8	3.5	3.8	4.5
Mining and quarrying	134.1	16.8	(88.0)	52.5	(14.5)
Manufacturing	2.4	(7.1)	0.4	4.6	4.9
Construction	6.2	(7.6)	5.1	6.7	5.1
Services	6.3	5.5	3.7	5.0	5.4
Finance insurance and real estate	2.9	1.6	4.7	4.3	4.6
Resource allocation impediments (percentage of firms)*					
Access to financial capital	–	–	–	–	39.7
Electricity (energy)	–	–	–	–	11.8
Access to land	–	–	–	–	11.4
Public interest payments	1.7	1.1	0.8	0.9	2.1
Consumption (distribution of finished goods and services)					
Public sector	0.3	(19.3)	24.2	37.9	21.5
Private sector	29.6	(15.1)	(0.2)	9.4	11.1
Investment	(15.8)	(5.3)	(15.2)	5.2	1.6
GDP growth	20.7	4.6	(21.1)	6.3	3.7
Net exports (current account)	(9.45)	27.09	(22.38)	(2.89)	(3.76)

* Challenges facing small- and medium-size enterprises (SMEs). Public interest payments are percentage of GDP.
Source: Statistics Sierra Leone (SSL) and World Bank (WB) *Staff Estimates*, and *Enterprise Survey* (World Bank, 2017, pp. 25 and 28).

Prima facie evidence shows that public sector consumption (in this case the dominance of government's presence in the credit market) is capable of crowding out private investment (Jackson and Jabbie, 2020). Small- and medium-enterprises (SMEs) are increasingly reliant on external sources of finance. As expected, the level of investment is exceedingly inconsequential; essentially because investment is contingent on access to financial capital. Therefore, in a 2017 survey, SMEs rank access to finance as the foremost binding constraint to competitiveness. In Sierra Leone, 65.1 percent of respondents cited the financial deficiency in contradistinction to an average of 38.3 for Sub-Saharan Africa (World Bank, 2017, p. 28). Interestingly, the lackluster performance of private investment has coincided with legislative effort to stimulate private investment. The Investment Promotion Act (2004) promulgates ambitious goals to attract private investment. However, consumption and distribution patterns, lower levels of corruption, and adherence to the rule of law are significant pull factors that cannot be subordinated to legislative intent.

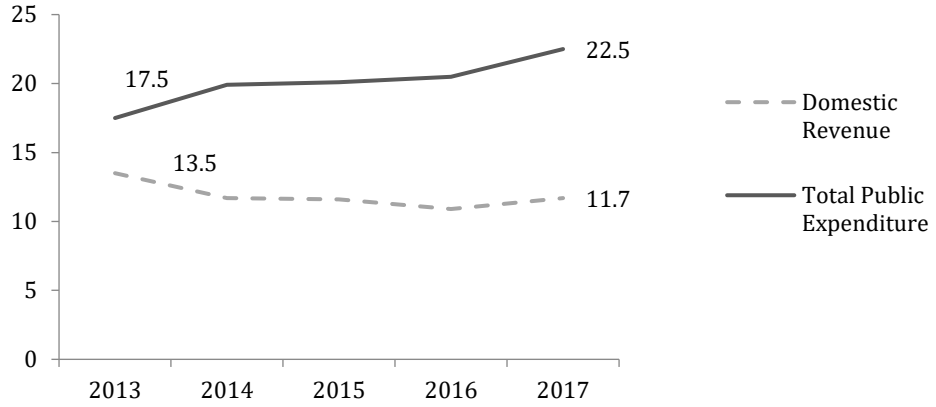
Inflationary pressures counterintuitively coexist with credit constraint. The central bank, Bank of Sierra Leone (BSL) has also maintained a tight monetary policy stance in periods of credit crunch. For example, the monetary policy rate (MPR), an equivalent of the short-term or Fed Funds rate, was increased from 11 percent in December 2016 to 12 percent in March 2017, and 13 percent in March 2017 (in increments of 100 basis points). Realistically, the monetary policy might not be too counterintuitive after all. That is, the dominant presence of the

government (Jackson and Jabbie, 2020) in the credit market crowds out domestic investment and puts upward pressures on the MPR, which further constrains investment (a double whammy). Between 2016 and 2017, credit to the government increased by 28.7 percent (Le 1,140.8 billion) as a result of government borrowing to finance fiscal deficit. Private sector credit grew by a mere 4.9 percent (66.6 billion) reflecting both liquidity constraints faced by banks and the general slowdown in economic activities. (World Bank, 2017, p. 27).

Notably, the central government has a towering presence in economic activity. The government drives economic growth through the consumption channel by exploiting the availability of credit, which negatively impacts the viability of the private sector to produce goods and services (Jackson and Jabbie, 2020). Table 1 occasionally shows tepid growth of public sector consumption, but the growth of public sector consumption outpaces that of the private sector after 2014. Bloated public expenditure can be unavoidably linked to a revenue gap; public sector consumption asymmetrically outsizes government revenue (see figure 1; also reference to Jackson and Jabbie, 2020).

Total public expenditure as a percentage of GDP increased from 17.5 percent in 2013 to 22.5 percent in 2017. The increase in expenditure occurred as receipt of domestic revenue (tax and nontax revenues) deteriorated from 13.5 percent to 11.7 percent during the same period. About 71 percent of the total public debt stock is estimated to be external and amortized in foreign currencies, thereby posing exchange rate risks. Predictably, the deficit was financed by IMF credit and a drawdown of reserves. External debt reached 43.0 percent of GDP (US$1.51 billion) in 2017 from 41.3 percent (US$1.34 billion) in the previous year, reflecting new borrowings from bilateral and multilateral creditors, with 75.2 percent of external debt being owed to multilateral creditors, such as the World Bank (WB), IMF, and the African Development Bank (AfDB) (World Bank, 2017, p. 35). Stringent contractionary policies have made it impractical for depository institutions to consistently meet their liquidity needs.

Figure 1 – *Public income-expenditure relationships* (*percent of GDP*)



Notes: Domestic revenue is a combination of tax and nontax revenues. Total expenditure is an aggregation of recurrent and development expenditures.
Source: Ministry of Finance and Economic Development (MoFED[1]) and WB *Staff Estimate* (World Bank, 2017, p. 34).

[1] Please note: this department is now divided into two separate ministries, namely the Ministry of Finance and Ministry of Development and Economic Planning. Many of the information that relate to data utilization in this work are now under the remit of the Ministry of Finance.

Government consumption of the sort naturally triggers a current account deficit, which results in capital inflows, as balance of payments accounting will suggest. The current account deficit of Sierra Leone was largely financed by increased inflows to the financial account. Inflows to the capital and financial account increased to 19.9 percent of GDP in 2017 from 16.3 percent in the previous year, driven mainly by long-term portfolio flows and foreign direct investment, especially in agriculture and mining. (World Bank, 2017, p. 37).[2]

Significantly, the paucity of credit is not peculiar to the manufacturing and service sectors. Despite the dominant presence of agriculture, farmers are equally constrained by inadequate raw materials and capital (high quality seeds, fertilizers, and machines), and access to credit (UNCDF, 2018). The backward or primitive (unscientific) land-tenure system, which is inconsistent with the market principles of modern economies, generates risks and inhibits long-term proprietary rights over investments. That is, there seems to be an uncanny insight that people will be willing to invest in what they do not own. More precisely, land is not a marketable resource in some areas of the country where it is badly needed for food production and possibly energy supply. The structure of the economy unequivocally reveals that the economy is less diversified and polarized in terms of accessing limited available resources, with the government maintaining dominant control over consumption and access to credit (Jackson and Jabbie, 2020). The macroeconomic deficiencies make stabilization a challenging and unconventional proposition.

2. Methodology and data

2.1 The econometric models

This paper uses a two-pronged approach to study the responses of monetary policy to perturbations (innovations/shocks) and the likelihood that alternative samples could have generated estimated parameters (Bayesian methodology) for a small open economy. The quantitative software, Eviews 10, is used for diagnostic and regression estimates, while MATLAB is used for prior and posterior estimations and representations in the appendix. The parsimonious VAR specification incorporates three interrelated sectors: (i) the nominal financial sector, proxied by the money supply, (ii) the real sector, represented by real GDP, and the foreign sector, captured by dependence on crude oil and the volatility of its price.

Since the efficacy of VARs depends on their stationarity, inter alia, or the extent to which the relevant variables can cointegrate, we follow the traditional paradigm of evaluating the long-run relationships of the variables by conducting a cointegration test to avoid the spurious regression problem. We preferably use the Augmented Dickey-Fuller (ADF) diagnostic test, which accounts for correlated errors and dynamism:[3]

[2] Short-term flows were not very volatile, which suggest that restrictions were placed on nonresident investment in short-term financial instruments (a form of sterilization).

[3] The Engle-Granger diagnostic test is based on the results of a regression after first verifying that the relevant variables are not stationary. For example, the variables in Equation 2, $y_t = \theta' x_t + e_t$, may not be stationary; however, Engle and Granger (1987) suggest that by estimating the cointegrating parameter, $\widehat{\theta'}$, in the equation, $\widehat{e_t} = y_t - \widehat{\theta'} x_t$ and subjecting it to a unit root test, the null hypothesis of no cointegration can be rejected when there is a stationary linear combination of the relevant variables (see Gujarati, **2004**, for the ADF representation).

$$\Delta y_t = \beta_1 + \beta_{2t} + \delta Y_{t-1} + \alpha_i \sum_{i-1}^{m} \Delta y_{t-1} + \varepsilon_t \quad (1)$$

where ε_t is for the error term, $\Delta Y_{t-1} = (Y_{t-1} + Y_{t-2})$. The lags are based on empirical estimates discussed before, but the error term becomes serially uncorrelated with larger the number of terms.[4]

Though the endogenous variables of interest are not individually stationary, we expect them to be collectively stationary and espousing a long-run relationship if they are cointegrated. Evidence of cointegration transforms the original specification of the VAR to a cointegrating specification:

$$\Delta y_t = \psi \Delta x_t + \gamma (y - \varphi x)_{t-j} + u_t \quad (2)$$

where γ is a cointegrating vector, and ψ and ρ are reparameterized representations of short- and long-run multipliers.[5]

The change in the endogenous variables in the system, Δy_t, is related to changes (growth) in other variables in the system Δx_t (with no intercept) and deviations from past equilibrium, $(y - \varphi x)_{t-j}$, with an intercept. The expression in parenthesis (equation 2) is the cointegrating relationship and gamma is the error correcting estimator (ECE), reflecting the required speed of adjustment to stabilize the endogenous variables. The ECE estimates the amount of disequilibrium in the previous period that is corrected to stabilize the endogenous variables.

A positive coefficient is indicative of divergence, while a negative coefficient indicates convergence. If the ECM is 1, then 100% of the adjustment takes place instantaneously. Alternatively, the ECM could adjust for 40% (0.4) or for nothing at all within a given period. Zero adjustment is probably unlikely after establishing a cointegrating relationship. Further diagnostic tests, coefficient test(s), a serial correlation test and dynamic stability test will not be discussed as part of the findings of this paper because of brevity and the empirical objectives of this paper (see Warburton 2018a and 2018b for further discussions of the tests).

The paper extends its inquiry by investigating the viability of the data, given the parameter estimates that were derived from the data. By so doing, we adopt an interdependent inquiry to evaluate parameter performance and data viability. Implicitly, we pose a probative question: can the estimated parameters be consistent with the probability of actual data and sample variations? The Bayesian methodology is rather instructive for this inquiry.

The probability of observing parameters (θ), given available data (ξ) [a posterior probability (function) for parameters], is proportional to the product of the probability of a likelihood function, $p(\xi|\theta)$ and the ratio of the prior probabilities for the parameters and the probability of having the actual data $p(\xi)$ (see equation 7). The posterior probability can be used as a *prior* probability in subsequent analysis. The likelihood function, which is actually a sampling density for the data[6] and the marginals, ($p(\theta)$) and $p(\xi)$, are scientifically presumed to be *prior* distributions for the parameters (θ) and the probability of the actual data (ξ).

[4] With corresponding p-values in parenthesis, CPI (0.99), crude oil prices (0.09), real GDP growth (0.192), and T-Bill (0.21), are diagnosed to have unit roots (to be nonstationary), which necessitates a cointegration test.

[5] See Hill et al. (2011, p. 491) for a derivation of the intercept (adjustment parameter); also discussed in Warburton (2018b, pp. 64-65 fn.) The ECT, the speed of adjustment parameter or feedback effect, is derived as the error term from the cointegration models whose coefficients are obtained by normalizing the equation on X_t and Y_t respectively.

[6] A constant makes it a proper (normalized) density function, a function that integrates to 1 (see Lynch, 2007, pp. 13 and 50).

If θ can collect all of the parameters of the model that we want to estimate when ξ denotes the available data that we use for the purpose of the estimation of these parameters, then the Bayesian rule is simply represented by:

$$p(\theta|\xi) = \frac{p(\xi|\theta)p(\theta)}{p(\xi)} \tag{3}$$

where p represents a probability distribution. Equation 3 is a posterior distribution, a conditional distribution of the parameters, given the data, that takes into consideration the joint distribution of the data, given the estimated parameters, the prior distribution of the parameters $p(\theta)$, and the marginal data density, $p(\xi)$. As such, $p(\xi|\theta)$ is a likelihood function that is equivalent to the conditional distribution of the data given the parameters of the model.

A *prior* distribution of the parameters characterizes the uncertainty about the parameters before observing the data. It is defined as a marginal distribution of the parameters, θ, denoting some amount of ignorance. Equation 3 provides a rather generic and multivariate VAR representation of equation 2. From a much more practical point of view, and consistent with the DSGE estimating approach, econometric models generally deal with multiple variables and solutions of simultaneous equations. Invariably, our variables of choice are macroeconomic and highly interdependent. Accordingly, we explore joint densities (densities with more than one economic variable).

Bayesian inference amounts to updating *prior* beliefs about the VAR parameters that are seen as stochastic variables after observing a sampled model. *Prior* beliefs about the VAR coefficients are summarized by a probability density function (pdf), and updated using Bayes' Law:

$$p\left(A, \Sigma \middle| \xi_{1-p:t}\right) = \frac{p(A,\Sigma)\, p\left(\xi_{1-p:t}|A,\Sigma\right)}{p\left(\xi_{1-p:t}\right)} \propto p(A, \Sigma) p\left(\xi_{1-p:t}|A, \Sigma\right) \tag{4}$$

where $A \equiv \left[A_1 \ldots, A_p, C\right]'$ as a kxn matrix, with $k = np + 1$.

The joint posterior distribution of the VAR(p) coefficients $p\left(A, \Sigma \middle| y_{1-p:t}\right)$ incorporates the information contained in the *prior* distribution $p(A, \Sigma)$, which summarizes the initial information about the model parameters, and the sample information summarized by $p\left(\xi_{1-p:t}|A, \Sigma\right)$.The posterior distribution summarizes the entire information available, and is used to conduct inference on the VAR parameters.

In order to obtain the posterior distribution, the joint distribution of the data and the parameters in equation (2) are divided by a marginal data density. This value is called marginal likelihood.[7] Although determining the probabilities for particular regions of multivariate densities is important, we are also interested in a subset of the dimensions of a multivariate density. Two types of "subsets" are frequently needed: marginal distributions and conditional distributions (Lynch, 2007, p. 23).

What is the value of the parameter that makes the data most likely to have occurred? Since the value of a parameter is contingent on the occurring probability of the data, the fundamental idea behind maximum likelihood estimation is to establish some sort of function that gives the

[7] A marginal data density summarizes the evidence in favor of the model contained in the data. The conditional distribution of a parameter (ρ), given available data (ξ), is just the joint density of ρ and ξ divided by the marginal distribution for ξ, where the marginal distribution is the distribution of one variable, integrating/summing over the other variables in the joint density (Lynch, 2007, p. 24):

$f(\rho|\xi) = \frac{f(\rho,\xi)}{f(\xi)}$; alternatively, $f(\xi) = \int_{\rho \in S} f(\rho, \xi)\, d\rho$.

probability for the data and the value of the parameter that maximizes the probability, which is called the "likelihood function":[8]

$$f(\xi|\theta) \equiv L(\theta|x) = \prod_{i=1}^{n} f(x_i|\theta) \quad (5)$$

where ξ denotes independent observations of a random variable, $x_1, x_2 \ldots x_n$ in a data set of n dimension. The multiplication rule in probability theory gives the joint probability for the vector ξ, represented by the product operator (Π).

How do we obtain the estimates for the parameters after we set up the likelihood function? Just as many pdfs are uni-modal and slope away from the mode of the distribution, we expect the likelihood function to look about the same. So, what we need to find is the peak of this curve. Calculus affirms that the slope of the curve should be 0 at its peak. Thus, we have taken the derivative of the likelihood function with respect to the parameter, set it equal to 0, and find the x coordinate (the parameter value) for which the curve reaches a maximum. The log specification provides feasible post-differentiation estimation in additive form, and the log likelihood reaches a maximum at the same point as the original function. Generically,

$$LL(\theta|\xi) = \sum_{i-1}^{n} \log\big(f(x_i|\theta)\big)$$

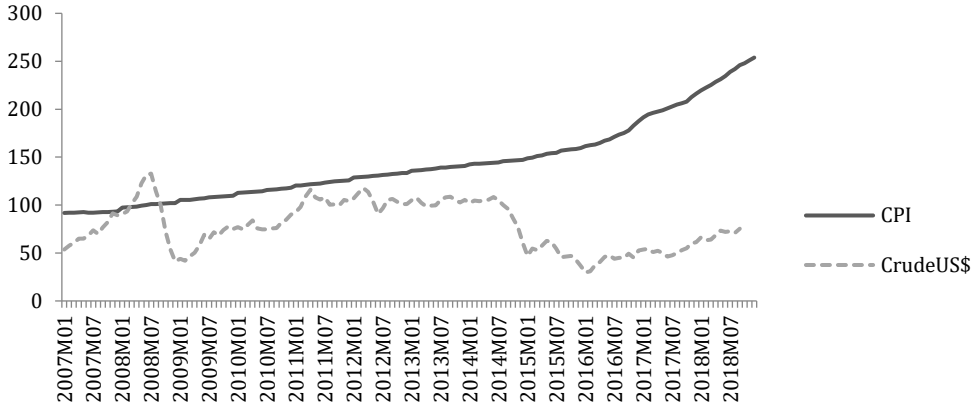
$$LL(p|x) \propto x_1 \ln p + x_2 \ln(1-p) \quad (6)$$

To find the value of p where this log-likelihood function reaches a maximum, we need to take the derivative of the function with respect to p, set it equal to 0, and solve for p.

2.2 The econometric variables

(i) *Oil prices and economic performance*

Figure 2 – *CPI (percent) and crude oil prices* (*US$, 2007-2018*)*



* Crude oil prices until September 2018.

[8] Parameter estimation involves 4 steps: (i) constructing the likelihood function, (ii) simplifying the likelihood function and taking its logarithm, (iii) taking the partial derivatives of the log- likelihood functions and setting the results equal to 0, and (iv) solving the system of equations for the parameter values. In the likelihood notation, the parameter and the data are interchangeably situated. The parameters are presumed to be fixed but there is interest in the specific values of the parameters, given the data.

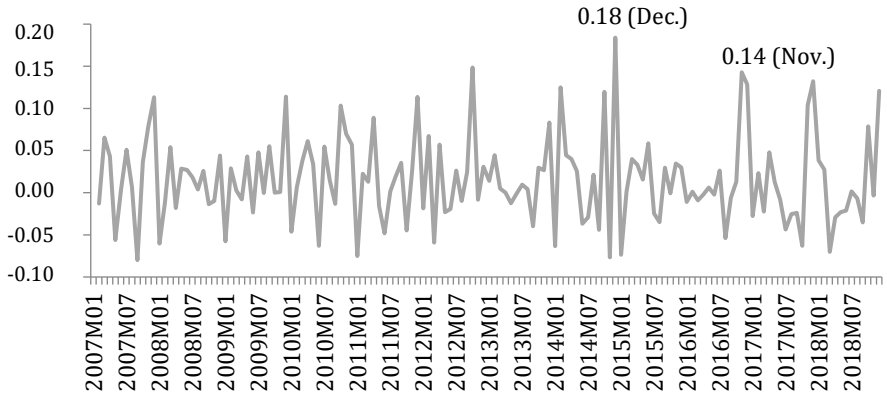
The impact of crude oil prices, herein denoted as Coil, which is also operationalized in average US dollars per barrel, seems to have very strange impact on the Sierra Leonean economy. This is partly because the country is not a major importer of actual crude oil with very low levels of manufacturing. Therefore, shocks to the crude oil prices do not persistently affect monetary policy though the shocks seem to have a persistent effect on national output; possibly through some unavoidable transmission mechanisms. We estimate expected values for October to December 2018. The next subsection examines the relevance of monetary policy rules to price stability.

(ii) *Money supply and interest rate*

The 364-days T-Bill – herein referred to as T-Bill – is the most influential asset of the government securities market in Sierra Leone, despite the low rate which started manifesting itself around the early part of 2013 on account of the increase in production and global price of Iron Ore. In fact, the T-Bill has not been an unusual monetary instrument to stabilize prices in large and small open economies. Revenue challenges, inadequate alternative investments, and the Ebola epidemic have increased reliance on this monetary instrument to stabilize the economy. Like the US treasuries, the T-Bill is considered to be risk-free instrument in Sierra Leone; partly because of perceptions of the continuity of the government that underlies low probability of default relative to corporate insolvencies. We estimate expected values for 2007.

Reserve requirements constitute a tool of monetary policy, but it has not been a very effective monetary tool. Indeed, the US reduced its emphasis on monetary aggregates in the 1980s and included money market conditions that were consistent with its policy goals. Realistically, it is not a tool that can be ignored, but it poses tremendous challenges for small open economies with a very robust informal sector. Figure 3 shows the volatility of reserve money growth between 2007 and 2018. It is generally difficult to associate the volatility with inflation, economic performance, or the need for liquidity in the aggregate economy. The empirical results are generally indicative of the underlying difficulties that are associated with the use and enforcement of this monetary tool.

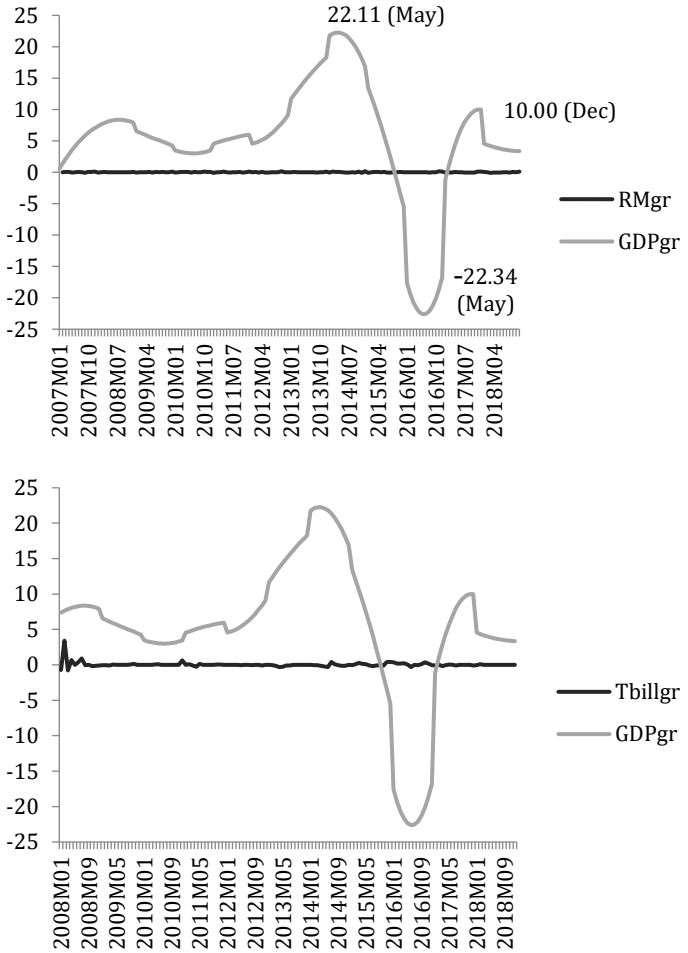
Figure 3 – *Reserve money growth* (*2007-2018*)



(iii) *National output*

In Sierra Leone, real GDP is computed on an annual basis (reference to figure 4). The data have been reconstituted to provide a realistic picture of monthly contributions to the real economy between the start of 2007 and the end of 2018. The Ebola epidemic and decline in the price of Iron Ore contributed to inherent weaknesses in the real sector and recovery has been rather weak or immediately sustainable.

Figure 4 – *GDP, reserve money, and T-Bill growth rates* (*percent, 2007-2018*)



3. Empirical analysis and conclusion

By first addressing the frequentist approach, we report some preliminary diagnostic tests. Two tests are unavoidable and preliminary in this tradition, the lag-length and stationarity (cointegration) tests. As stated earlier, for the sake of brevity and empirical objectives of this

paper, we do not engage in elaborate and ancillary tests for model stability and parameter significance; we believe that the comparative performance of models will suffice after obtaining the results of the preliminary diagnostic tests. Table 2 reports the lag-length diagnostic test for 140 observations. The Schwartz information criterion (SC) is preferred because of the monthly structure of the data and consideration of the number of parameters to be estimated. We reasonably prefer parsimony in order to avoid the over-parameterization problem. Models with long lags lead to a rapid loss of degrees of freedom and over-parameterization (overfitting).[9]

Table 2 – *Lag-length diagnostics*

Lag	logL	LR	FPE	AIC	SC	HQ
0	–2080.177	NA	5949739.	29.78824	29.98330	29.83093
1	–1020.336	2028.839	2.260695	15.00480	15.63515*	15.26095
2	–972.7164	87.75539*	1.638696*	14.68166*	15.83731	15.15128*
3	–954.1042	32.97022	1.801370	14.77292	16.45386	15.45600

* indicate lag order selection by the criterion.
LR: sequential modified LR test statistic (each test at 5% level). FPE: Final prediction error. AIC: Akaike information criterion. SC: Schwartz information criterion. HC: Hannan-Quinn information criterion.

As an extension of the frequentist tradition, we examine the stationarity of the traditional VAR model by conducting a cointegration test. We report the findings in table 3.

Table 3 – *Unrestricted cointegration test*

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None*	0.427999	159.9888	69.81889	0.0000
At most 1*	0.270366	81.22410	47.85613	0.0000
At most 2*	0.113953	36.77925	29.79707	0.0067
At most 3*	0.080769	19.72040	15.49471	0.0108
At most 4*	0.054123	7.845660	3.841466	0.0051

Notes: Trace test indicates 5 cointegration eqn(s) at the 0.05 level.
* denotes rejection of the hypothesis at the 0.05 level.
** MacKinnon-Haug-Michelis (1999) p-values.

As expected, the variables are cointegrated and by tolerating a 5% error, we fail to reject the null of no cointegration. In effect, the macro variables for the small open economy – reserve

[9] The classical (frequentist) estimation may or may not yield precise information because model specification is contingent on the amount and quality of endogenous variables when the number of parameters to be estimated geometrically grows with the number of variables (n) and lags (p) – $n(np+d)$; where d is for the number of constants.

money inflation, national output, and T-Bills, exhibit some amount of long-run relationship (interdependence) and the residuals are collectively stationary (see also appendix E). Further, as Ciccarelli and Rebucci (2003) discovered, a Minnesota-type *prior* is capable of performing reasonably well in the presence of cointegrated data. The findings of the paper are reported in the next section.

We find that the frequentist and Bayesian analyses of monetary policy responses to exogenous perturbations in a small open economy do not provide significant evidentiary variations. The patterns of the frequentist responses exhibit no significant difference from the Bayesian responses to inflation and disturbances that are associated with crude oil prices. Using T-Bills as a more reliable instrument of monetary policy, disturbances that are associated with crude oil prices have immediate positive impact on monetary policy, but the impact is not persistent. It dissipates after a period of about five months. A similar result was also uncovered for the impact of crude oil disturbances on reserve money. The impact is also immediate but rather ephemeral (see appendix C).

Unlike the impact on T-Bills, the effect of crude oil perturbations on national income is much more persistent and generally lasts for more than a year. Notably, the persistence is in spite of the view that the crude oil own-shock converges slowly. However, while the frequentist approach captures the immediate positive impact of the own-shock, the Bayesian response captures the slow convergence without the immediate impact.

We note that the effects of inflation on GDP and T-Bills are somewhat different. While the effects on T-Bills are rather flat, the response of output to inflation shock is relatively persistent. Crude oil prices can indirectly impact the cost of producing goods and services in a small open economy. Therefore, the variables can be confounding. For the small open economy, we find that the frequentist and Bayesian approaches cannot cleanly differentiate the effects of an inflation shock on GDP and T-Bills. Evidently, on all occasions, the impact of inflation on output is more persistent; partly because the dominant monetary policy instrument (T-Bill) shows no significant response to neither an inflation shock or shock to crude oil prices (see appendix C).

In appendix D, we consider a variety of primitive assumptions (*priors*) about the macro variables to see if output and monetary policy responses to disturbances in crude oil prices can be significantly different. The nature of the *priors* or primitive assumptions does not present significant variations in the posterior responses of output and monetary policy to perturbations that are associated with crude oil prices. Further, the responses are generally consistent with the frequentist approach embodied in the cointegration methodology. This finding affirms the theory that the movement from parameter estimates to impulse response functions is a significant econometric development.

While the effect on monetary policy dissipates within a year, the effect of crude oil prices on national output is explosive even though the crude-oil-own-shock shows a tendency to converge rather slowly (see appendices C and D), suggesting that a transmissive effect that runs from crude oil prices to inflation is a real possibility. Additionally, the form of primordial ignorance that is presumed does not provide any significant evidentiary abnormality in the response of the variables to exogenous shocks (see appendix D). The lack of posterior variation can be attributed to the dependence of primordial ignorance (*prior*) on the available data.

We turn to Granger-Causality tests for further clarification and affirmation. Table 4 examines the extent to which past values of the variables have explanatory powers over one

another. The Granger tests provide some corroborative value for evaluating the frequentist and Bayesian findings of this paper that may otherwise have been less apparent.

Tables 4a and 4b – *Granger-Causal relationships* (*block exogeneity Wald test*)*

4a – *Dependent variable: T-BILL*

Excluded	Chi-sq	df	Prob.
RMGR	1.776503	1	0.1826
GDP GR	13.43530	1	0.0002
CROIL	4.821663	1	0.0281
CPI	1.582295	1	0.2084
All	**15.86737**	**4**	**0.0032**

4b – *Dependent variable: GDPGR*

Excluded	Chi-sq	df	Prob.
TBILL	9.540617	1	0.0020
RMGR	0.151366	1	0.6972
CROIL	1.441246	1	0.2299
CPI	0.058833	1	0.8083
All	**20.00417**	**4**	**0.0005**

* 1 lag with 142 included observations.

Regression 4(a) shows that past value of crude oil prices and GDP growth have some explanatory power over the use of the T-Bill monetary instrument. Analogously, the past performance of T-Bill sales/purchases has some impact on GDP growth. Implicitly, there is a dual Granger-causality between T-Bill policy and real GDP growth. However, the impulse response functions show a weak relationship that is reminiscent of the ocular representation of figure 3.

Tables 4c and 4d – *Granger-Causal relationships* (*block exogeneity Wald test*)*

4c – *Dependent variable: CROIL*

Excluded	Chi-sq	df	Prob.
TBILL	1.738464	1	0.1873
RMGR	0.278223	1	0.5979
GDP GR	0.021957	1	0.8822
CPI	0.823970	1	0.3640
All	**3.234141**	**4**	**0.5194**

4d – *Dependent variable: CPI*

Excluded	Chi-sq	df	Prob.
TBILL	1.852710	1	0.1735
RMGR	14.07378	1	0.0002
GDP GR	4.739829	1	0.0295
CROIL	1.049345	1	0.3057
All	**35.82569**	**4**	**0.0000**

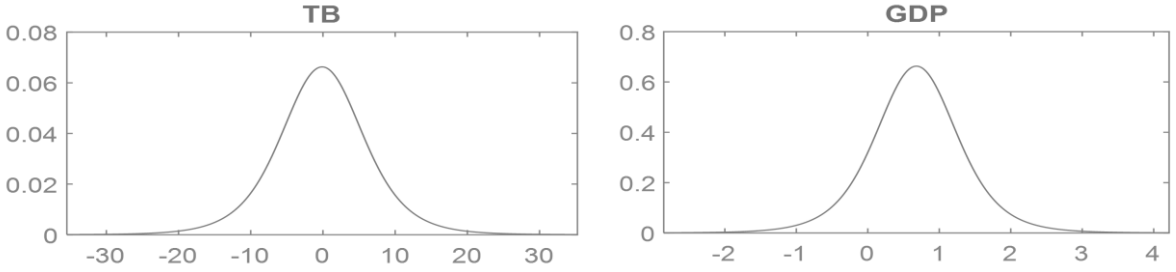
* 1 lag with 142 included observations.

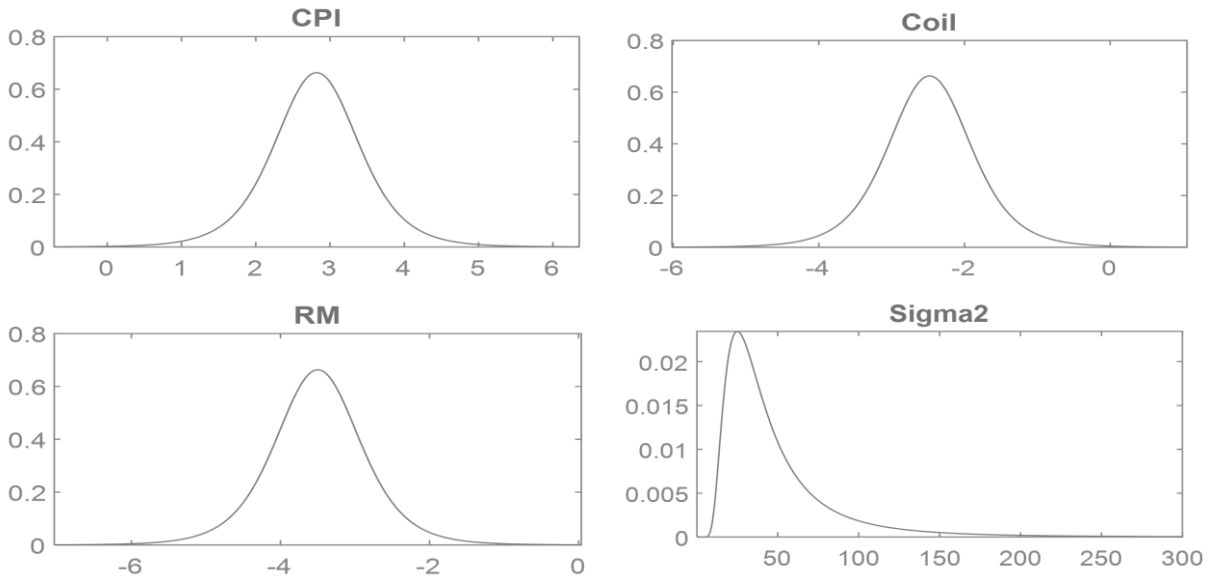
As expected, and consistent with economic theory, Regression 4c shows that the internal conditions in the small open economy do not affect crude oil prices. All of the internal variables are collectively insignificant and they naturally provide no explanatory value for explaining the vagaries of crude oil prices. Regression 4d is particularly instructive for an effective monetary policy. Past GDP and reserve money growth provide more explanation for the inflationary situation. The ineffective control over currency circulation creates preconditions for uncontrolled liquidity, sustained aggregate demand (relative to output), and demand-pull inflation.

In effect, multiple estimating procedures show that monetary policy does not seem to provide a robust resistance to external shocks and the effects of external shocks do not have persistent effect on monetary policy. The informal sector (Jackson, 2020a) poses a challenge for rule-based monetary policy, a stable currency ratio, and the provision of liquidity to foster economic growth while stabilizing prices. Accordingly, in the small open economy, the prospects of an effective monetary policy response to exogenous shocks will be contingent on central bank autonomy, sustainable investment, reduction in the size of the informal sector, and a reasonably well coordinated infrastructure for consequential and enforceable reserve requirements (Jackson et al., 2019a). Internal macroeconomic conditions (notably exchange rate crisis, trade deficit, corruption, etc.) in a small open economy make it less likely for central banks to robustly react to external shocks (Kallon, 2003; Bangura et al., 2012; Jackson, 2020b; Jabbie and Jackson, forthcoming).

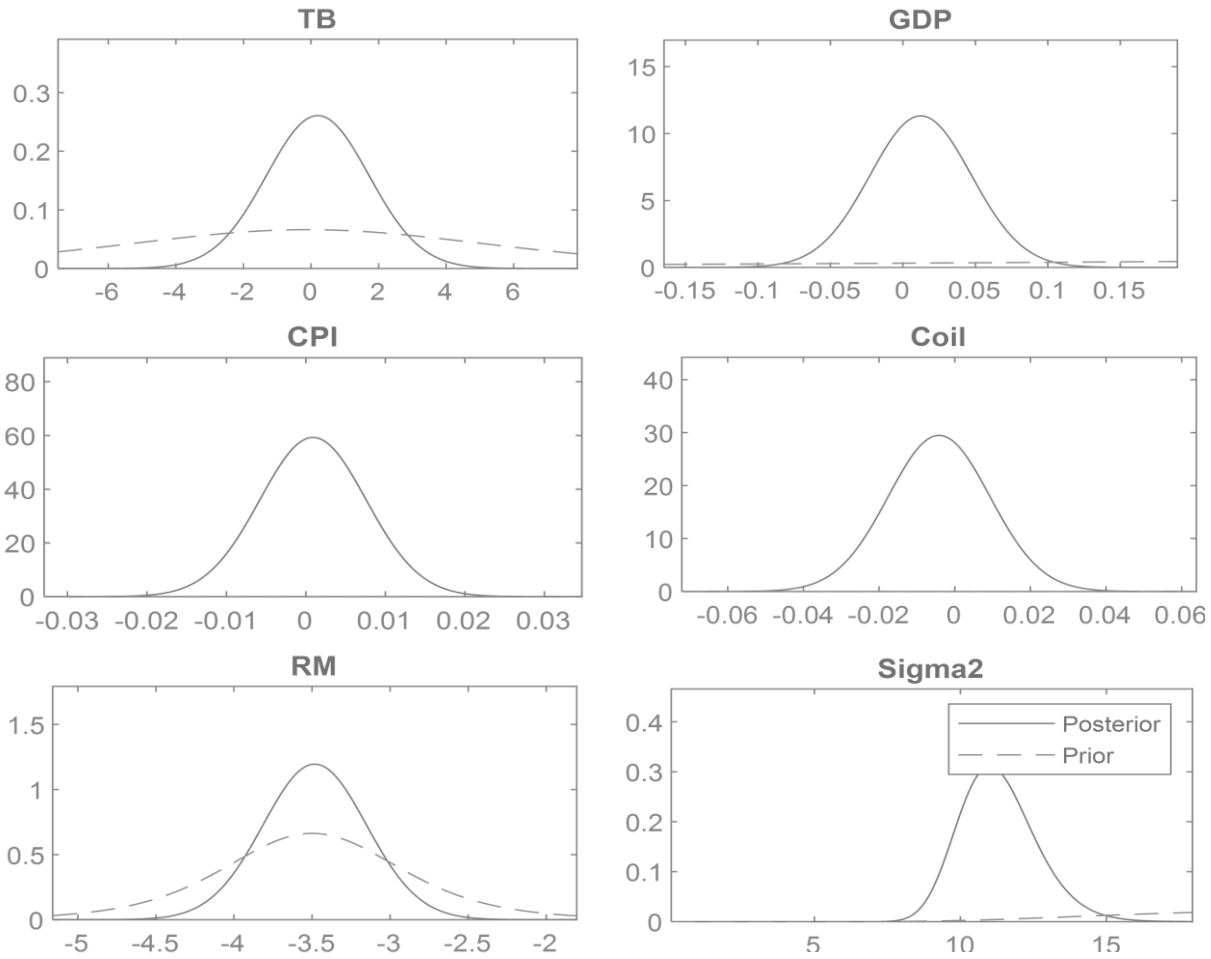
Appendix A – Likelihood function: reserve money growth

AI – *PRIORS*





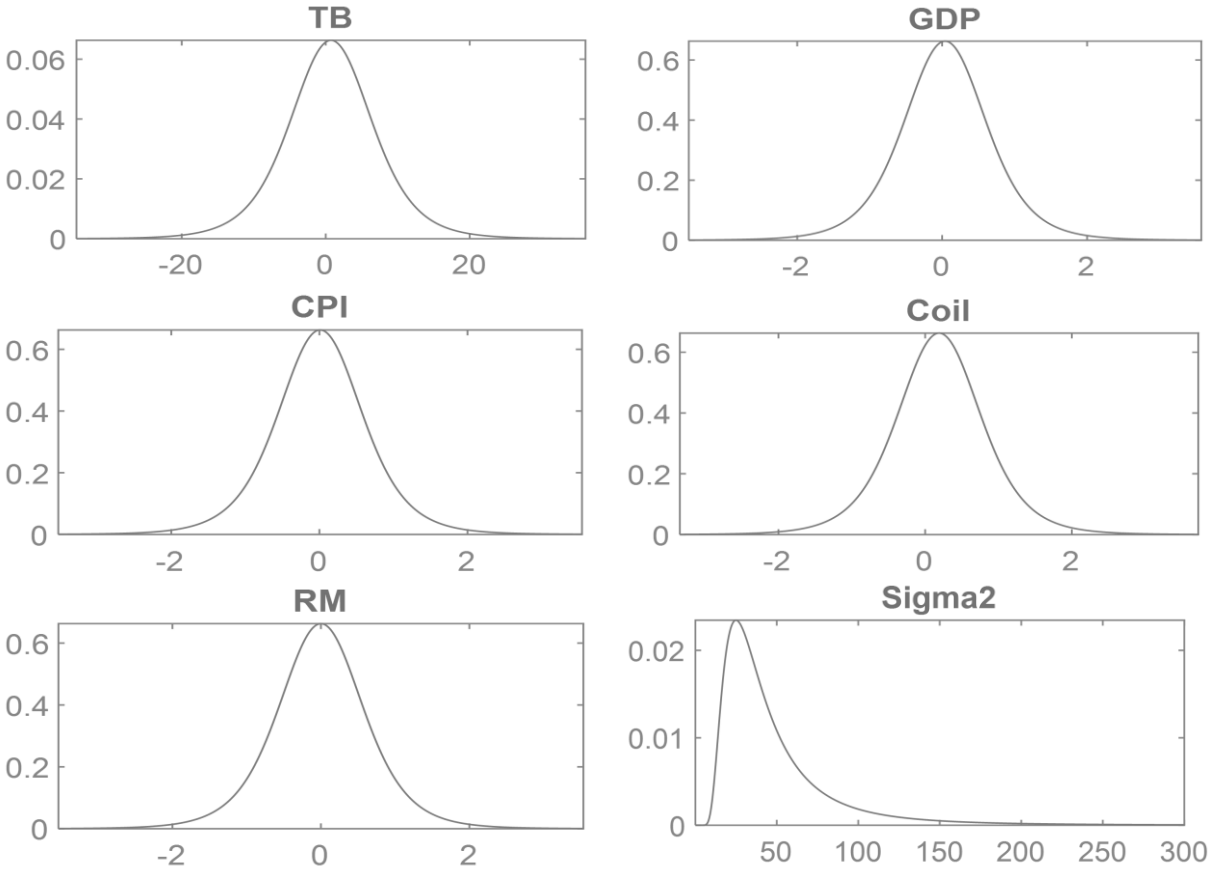
AII – *PRIORS* AND POSTERIORS



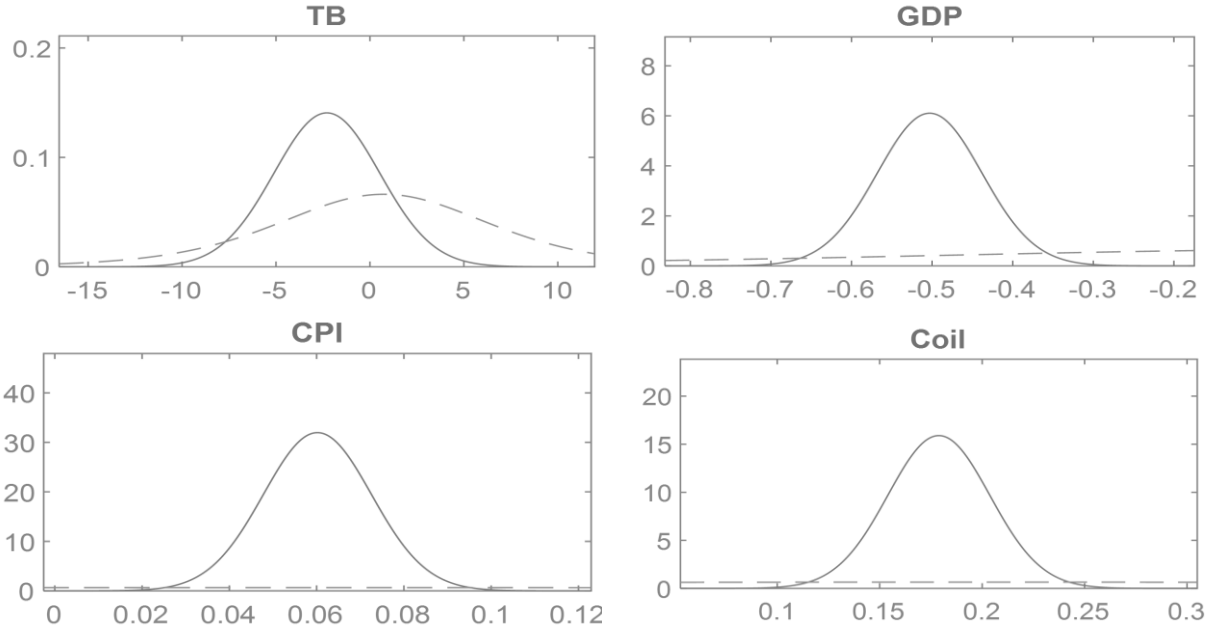
Notes: TB= Treasury Bills, GDP = real GDP growth, Coil= crude oil prices, and RM= reserve money growth.

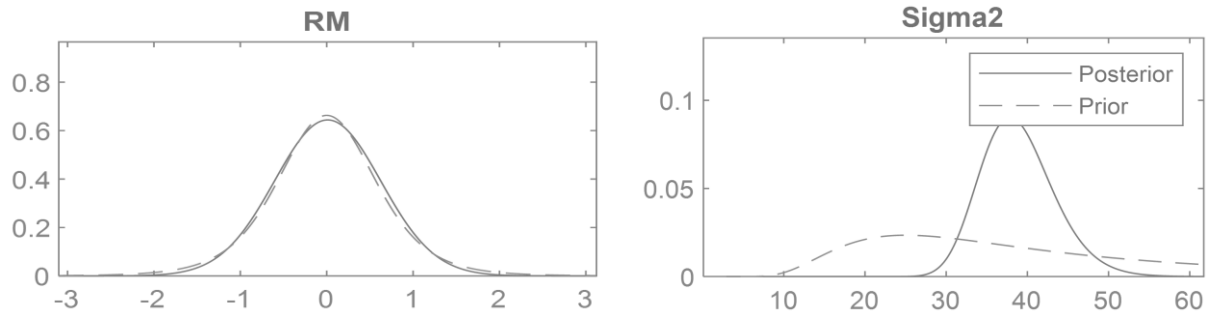
Appendix B – Likelihood function: T-Bills

BI – *PRIORS*



BII – *PRIOR* AND POSTERIOR DISTRIBUTIONS

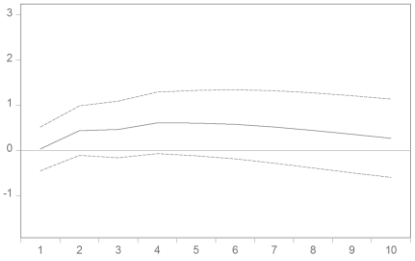




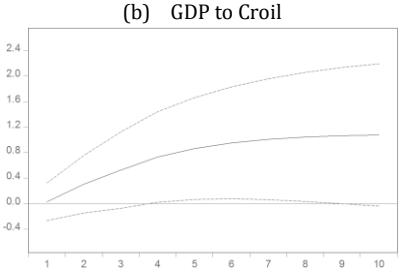
Appendix C – Comparative responses to shocks/perturbations

(i) Cointegrated v. Bayesian impulse responses:

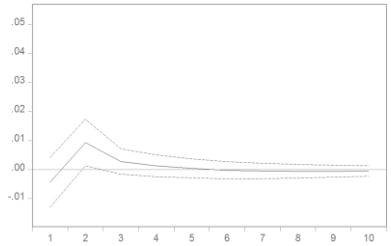
(a) T-Bills to Croil



(b) GDP to Croil

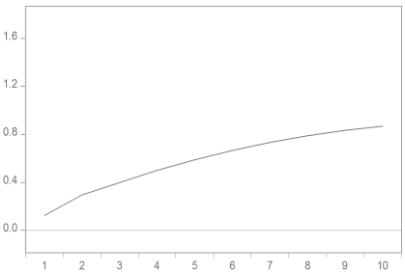


(c) Reserves to Croil

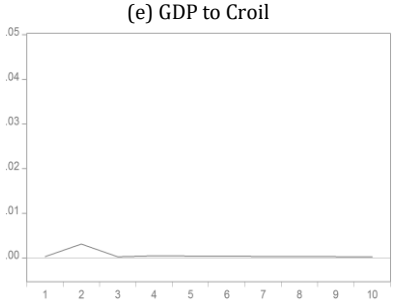


Bayesian impulse responses to crude oil innovations (Minnesota *prior*)

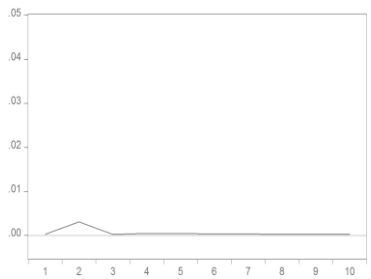
(d) T-Bills to Croil



(e) GDP to Croil

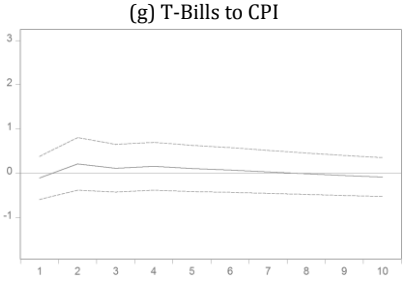


(f) Reserves to Croil

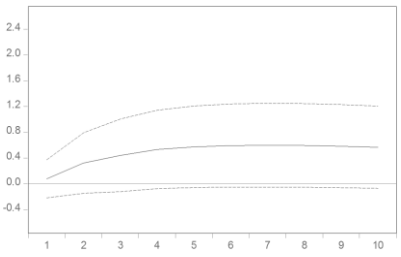


(ii) Cointegrated v. Bayesian impulse responses to inflation:

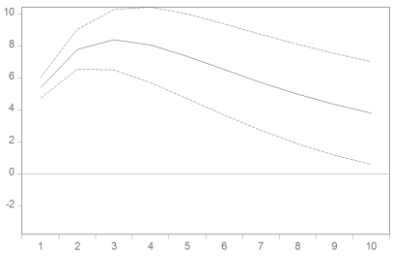
(g) T-Bills to CPI



(h) GDP to CPI

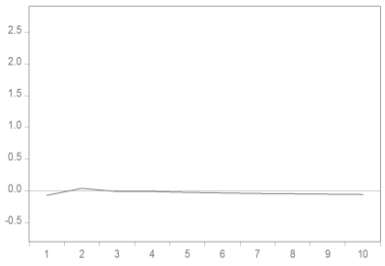


(i) Croil to Croil

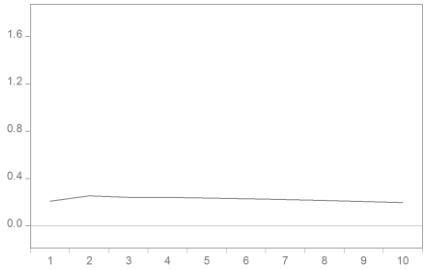


Bayesian impulse responses to inflation innovations (Minnesota *prior*)

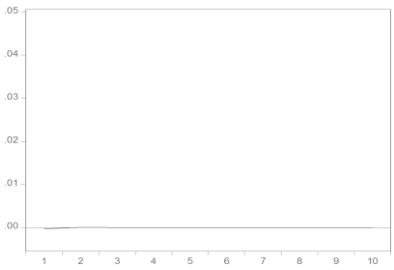
(a) T-Bills to CPI



(b) GDP to CPI



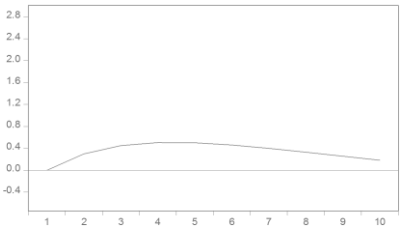
(c) Reserves to CPI



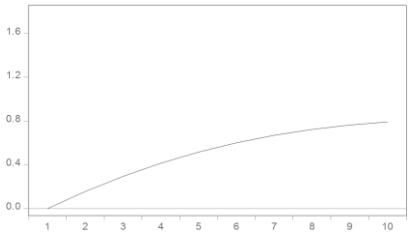
Appendix D – Comparative analysis of *prior* and posterior assumptions

Bayesian impulse responses to crude oil disturbances (Minnesota *prior*)

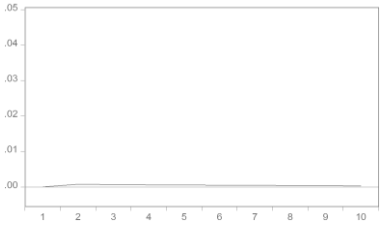
(a) T-Bills to Croil



(b) GDP to Croil

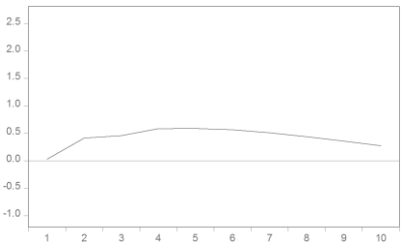


(c) Reserves to Croil

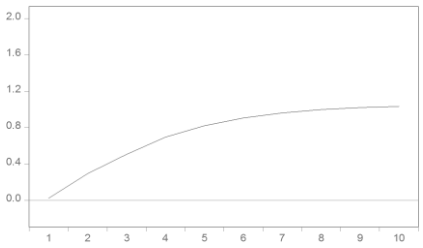


Posterior with normal Wishart-*prior*

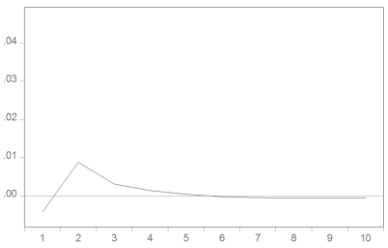
(d) T-Bills to Croil



(e) GDP to Croil

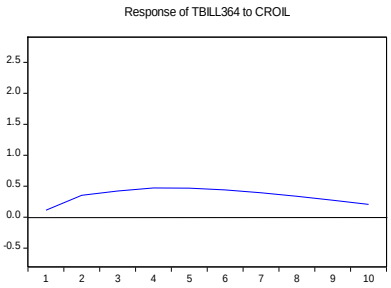


(f) Reserves to Croil

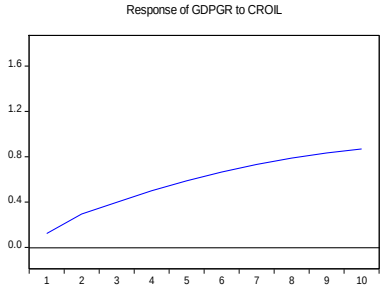


Posterior with Sims-Zha (Normal-Flat *Prior*)

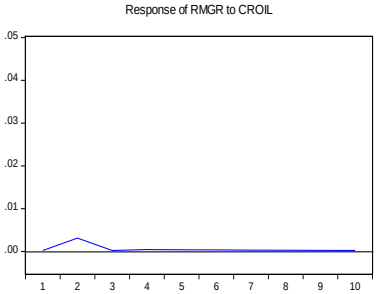
(g) T-Bills to Croil



(h) GDP to Croil

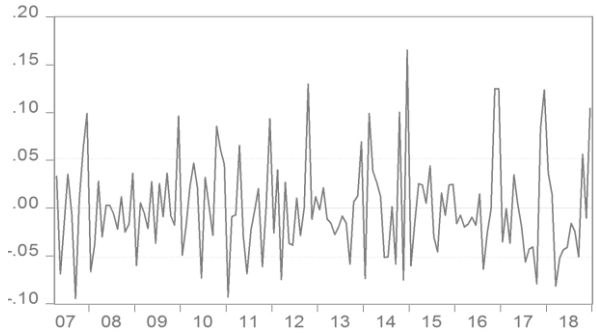


(i) Reserves to Croil

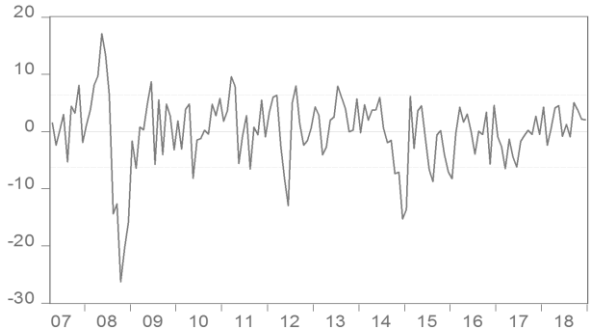


Appendix E – VAR residuals

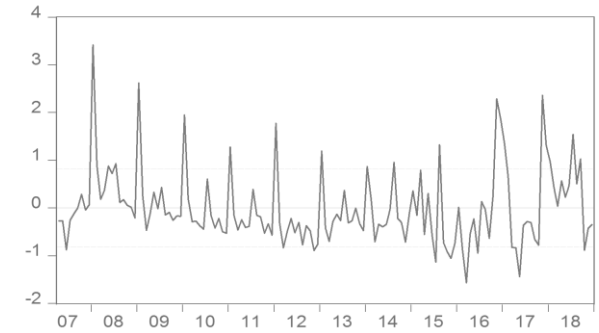
(a) RMGR



(b) CROIL residuals

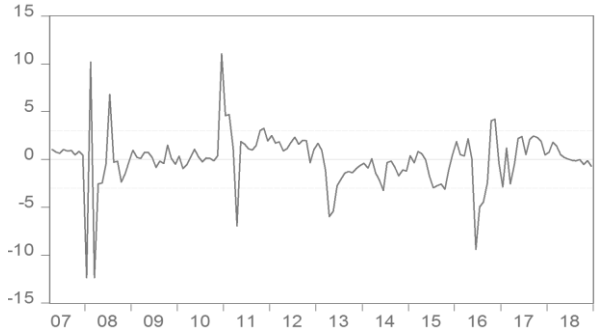


(c) CPI residuals



(d) GDP GR residuals

(e) TBIL364 residuals



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