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Fiscal and monetary policy rules in Malawi: a New Keynesian DSGE analysis

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Abstract

In this paper, Malawi's fiscal and monetary policy rules are estimated and their effects and influence on key macroeconomic variables analyzed in a New Keynesian DSGE framework. Bayesian estimation is used to estimate the model using data on consumption, investment, inflation, nominal interest rate, government spending, consumption tax revenue, and income tax revenue. It is found that monetary policy in Malawi follows a Taylor type interest rate rule in which interest rates respond strongly to changes in inflation, in accordance with the "Taylor principle", and only mildly to output fluctuations. Fiscal policy too reacts to output fluctuations in a modest fashion. With regards to the main drivers of output fluctuations, it is shown that although fiscal and monetary policy shocks play a significant role, it is actually productivity shocks and to a lesser extent cost-push and preference shocks that are the main contributors to business cycles.

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1. Introduction

Traditionally, macroeconomic theory regarded the moderation of business cycles and stabilization of prices as the dual objectives of macroeconomic policy. The work of Taylor (1993) helped solidify this view by proposing the “Taylor rule” in which central banks were recommended to adjust nominal interest rates in response to deviations of inflation and output from the inflation target and potential GDP respectively. In practice however, implementation of policy that simultaneously targets these two objectives can be challenging particularly when macroeconomic shocks result in stagflationary pressures. In such cases, choices have to be made regarding which policy objective to prioritize. Furthermore, fiscal and monetary authorities do not always have the same priorities and at times work in ways that undermine each other thus making it even more difficult to achieve the dual objectives.

Given the above challenges, a substantial amount of research has been dedicated to studying various topics that surround fiscal and monetary policy. Some studies such as Schmitt-Grohe´ and Uribe (2006), Orphanides (2003), and Philippopoulos, et al (2015) have focused on the optimal design of fiscal and monetary policies, others like Eichenbaum and Evans (2005) have investigated the effectiveness of the policies on some key macroeconomic variables, and others have examined the extent to which some recommended policy rules have been adopted in certain countries (Taylor (2012), Clarida, Galì and Gertler (2000)).

In this study, we look at the case of Malawi and examine the fiscal and monetary policy rules that have been adopted by the authorities and how these rules affect the economy. Additionally, the study also explores the relative importance of fiscal shocks, monetary shocks, and other macroeconomic shocks in influencing the real economy and price dynamics. In order to achieve these objectives, 3 main tasks are carried out. First, we estimate feedback rules for the nominal interest rate, government spending, income taxes, and consumption taxes. Secondly, we analyze how shocks to the estimated policy feedback rules affect key macroeconomic variables. And thirdly we examine the relative importance of the policy shocks, productivity shocks, consumer preference shocks, and price mark-up shocks on key macroeconomic variables.

The study takes advantage of recent advances in New Keynesian DSGE (herein after NK-DSGE) modeling which has seen a number of salient features being incorporated in the modelling framework in an effort to improve upon the traditional models. For instance, many NK-DSGE models now incorporate capital accumulation as is done in RBC models, and some also include a variety of structural shocks in order to capture the idea that other shocks besides monetary policy and productivity shocks may be equally important in determining the performance of the economy[1]. The model that we develop here also incorporates the above features thus making it the first of its kind developed for the analysis of the Malawi economy.

In line with the growing popularity of estimating DSGE models in lieu of calibration, our model is also estimated. Specifically, we employ the Bayesian method in order to estimate the main parameters of interest including the coefficients on the feedback policy rules. The Bayesian method happens to be an attractive technique for estimating DSGE models given its ability to allow for the a priori imposition of the ranges that parameters may take. This is an improvement on calibration given that data is allowed to dictate the final values of the parameters of interest whilst

[1] e.g. Ireland, P.N (2004), Smets and Wouters (2003, 2007) incorporate at least 5 shocks in their models

ensuring that the results maintain conformity to what is theoretically acceptable. More details on the Bayesian approach are provided in section 2 below.

With regards to our findings, our study shows that monetary policy in Malawi follows a Taylor type interest rate rule whereby nominal interest rate respond strongly to inflation but only minimally to output fluctuations. Interest rate smoothing also features significantly in the setting of monetary policy. As for fiscal policy, the reaction of government spending and the two tax policies in response to output fluctuations is also found to be moderate. In terms of the effectiveness of the two types of policies, we find that both fiscal and monetary policy shocks affect output and prices in the conventional ways although it is actually productivity shocks and to a lesser extent consumer preference shocks and cost-push (price mark-up) shocks that are the major drivers of business cycles in Malawi.

2. Literature review

2.1 New Keynesian DSGE Models

The history behind the development of New Keynesian DSGE models has been well documented by many.[2] In this section we try to avoid a regurgitation of this information, and instead focus on providing a brief overview of where NK-DSGE models stand as of today. Specifically we provide a brief review on what new features have been added to the models and what this means for researchers and policy makers.

New Keynesian DSGE models continue to play an important role in the analysis of macroeconomic policy and shocks. In their simplest form, these models comprise of only 3

[2] see Gali (2008)

equations namely: the dynamic IS equation (DIS), the new Keynesian Phillips Curve (NK-PC), and the monetary policy rule. While such model simplicity is desirable, it comes at the cost of realism and the ability of the models to capture certain important features of the economy. As such, many researchers have put a lot of work into the development of these models in a bid to enhance their ability in replicating real life observations.

One of the main issues in NK-DSGE modelling that has continued to put realism at odds with model simplicity is the inclusion of capital accumulation in the models. Common sense dictates that NK-DSGE models should include capital evolution given the role that investment dynamics play in Keynesian economics. However, doing so brings about modelling complications often in the form of absurd results. Traditionally the solution has been to simply ignore the capital accumulation equation all together (e.g Gali (2008), and Ireland (2004)). However researchers working with bigger models have found ways of incorporating this equation, some by introducing capital adjustment costs (Smets and Wouters (2003, 2007), and Christiano, Eichenbaum, and Evans (2005)), and others maintaining the standard law of motion for capital (Schmitt-Grohe and Uribe (2006), Philippopoulos,Varthalitis, and Vassilatos (2014)). The model that we use in this study follows the latter.

Another important improvement to NK-DSGE modelling has been the inclusion of fiscal policy in the models. Fiscal policy is also an important piece in Keynesian economics given that it is given a significant role for macroeconomic stabilization. Furthermore, incorporating fiscal policy in NK-DSGE models not only makes the models more realistic and more in line with Keynesian economics, but it also opens up doors for researching many other pertinent macroeconomic policy topics within the NK-DSGE framework. For instance, some researchers have now used NK-DSGE models to analyze fiscal and monetary policy interaction, (Furlanetto

(2012)), and others to study optimal fiscal and monetary policy rules (Schmitt-Grohe and Uribe (2006), Philippopoulos,Varthalitis, and Vassilatos (2015)).

Other notable developments in the NK-DSGE modelling framework include: the ability to study multiple types of macroeconomic shocks,[3] and the inclusion of other sources of nominal rigidities such as sticky wages and sticky information[4]. All these developments have enhanced the performance and usefulness of NK-DSGE models thus leading many policy makers into adopting them for their macroeconomic analysis and policy formulation. Furthermore, the introduction of Bayesian estimation of the models has enhanced their attractiveness by making them much more data guided than is the case with calibration, while simultaneously retaining theoretical guidance more than maximum likelihood (ML) estimation does. We explore this last point more detail next.

2.2 Bayesian Estimation

Bayesian estimation of DSGE models continues to gain popularity as the alternative to model calibration and ML estimation. The Bayesian technique is roughly a combination of calibration and ML estimation and as such it possesses the advantages that the two techniques have while at the same time addressing some of the problems with them. This section summarizes some of these advantages most of which have been well documented in the Bayesian estimation literature. But before going into that, a brief discussion on the implementation of the Bayesian method in DSGE modelling is in order.

Let $\boldsymbol{\theta}$ denote a vector of parameters in a model and $\boldsymbol{y^T} \equiv \{\boldsymbol{y_t}\}_{\boldsymbol{t=1}}^{\boldsymbol{T}}$ denote observable data for some of the variables in the model. As the name suggests, the Bayesian estimation method

[3] Smets and Wouters (2003) for instance analyzed up to 10 shocks
[4] See Mankiw and Reis (2002) for a discussion on sticky information

makes use of Bayes theorem of probabilities by linking the likelihood function of the model, $L(\boldsymbol{\theta}|\boldsymbol{y^T})$ (defined as the conditional probability density, $p(\boldsymbol{y^T}|\boldsymbol{\theta})$), with the prior beliefs on the model parameters, $p(\boldsymbol{\theta})$, to produce the estimated parameter distributions (posterior distributions) $p(\boldsymbol{\theta}|\boldsymbol{y^T})$. Specifically, the posterior distribution is given as:

$$p(\boldsymbol{\theta}|\boldsymbol{y^T}) = \frac{p(\boldsymbol{y^T}|\boldsymbol{\theta})\, p(\boldsymbol{\theta})}{\int_{\boldsymbol{\theta}} p(\boldsymbol{y^T}|\boldsymbol{\theta})\, p(\boldsymbol{\theta})\, d\boldsymbol{\theta}}$$

where the denominator $\int p(\boldsymbol{y^T}|\boldsymbol{\theta})\, p(\boldsymbol{\theta})\, d\boldsymbol{\theta}$ is the marginal likelihood, a useful tool for assessing model performance. As mentioned above, compared to other methods this setting provides us with some advantages which include but are not limited to the following.

i. The specification of prior beliefs in the Bayesian approach enables us to restrict our computational search to the parameter spaces that make theoretical sense. This is a very attractive feature in the estimation of DSGE models since DSGE models are highly susceptible to having multiple local maxima or flat parameter distributions, in which case the search is likely to end up in the wrong region. This is an advantage that parameter calibration also possesses albeit in a more aggressive manner, but one that ML doesn't.

ii. While ML estimates are easier to obtain in simpler models, in more complex models it is the Bayesian method that delivers estimates without much extra computational complexities. This is because for Bayesian estimation, deriving the posterior distribution only requires the two inputs, $p(\boldsymbol{\theta})$ and $p(\boldsymbol{y^T}|\boldsymbol{\theta})$, no matter how complex the model is. The only challenge that model complexity poses for Bayesian estimation is on calculating the likelihood function, a challenge also faced with ML estimation. Nevertheless, tools like the Kalman filter or particle filters have made it possible to easily to estimate $p(\boldsymbol{y^T}|\boldsymbol{\theta})$ numerically thus making it easy to proceed with the Bayesian method.

iii. Although the idea of incorporating prior beliefs in estimations can be criticized for its subjectivity, the Bayesian method allows for very flexible or non-informative priors, in which case the estimation of the parameters relies more on the data. As such, one can maintain complete agnosticism on one set of parameters while making use of prior beliefs about another set with a much stronger theoretical and/or empirical backing.

iv. The Bayesian model selection strategy is very compelling as it makes it possible to compare multiple models at the same time. This is not the case with frequentist methods whereby only two models are evaluated at a time.

For these and other reasons, various studies have employed the Bayesian method to estimate and/or evaluate the performance of DSGE models. This has been made possible thanks to the pioneering work of DeJong et al. (2000), Schorfheide (2000), and Otrok (2001). DeJong et al. proposed the use of Bayes theorem in estimating macroeconomic models with the aim of incorporating macroeconomic theory into empirical estimations. As for Schorfheide, his work focused on the usefulness of the Bayesian approach in evaluating the performances of different models, while Otrok's contribution was to apply the approach to the estimation of the welfare costs of business cycles.

Adding to the support of adoption of the Bayesian approach, Fernández-Villaverde and Rubio-Ramírez (2004) showed that for the Bayesian methods, not only did they possess asymptotic properties of classical methods, but could also outperform ML estimates as was the case in their application of the Bayesian method to the "Cattle Cycles" model of Rosen et al. (1994).

Others notable works on the applicability of the Bayesian approach include Smets and Wouters (2003) who estimated a DSGE model for the Euro area in which they incorporated various features including habit formation, capital adjustment costs, and variable capacity utilization. In this study they showed that the estimated model performed as well as both the standard VAR model and the Bayesian VAR model estimated on the same data. As for the models that they estimated for the US economy in their 2007 paper, they found that their Bayesian DSGE estimation improved on the forecasting performance of the standard VAR model and performed just as good as the Bayesian VAR model.

For a much more detailed review of the literature on the formulation and estimation of DSGE models using Bayesian methods, the reader is referred to the works of Fernández-Villaverde (2010), Geweke et al. (2011), and Herbst and Schorfheide (2016).

3. The model

In this study, our analysis is based on a NK-DSGE model featuring monopolistic competition among producers and Calvo type price rigidities. The model closely follows that of Philippopoulos et al. (2014) and to a lesser extent that of Schmitt-Grohe´ and Uribe (2006). However we deviate from these two models on two main fronts. Firstly, we introduce time varying consumer preferences and price mark-ups which allows us to analyze the roles that preference shocks and mark-up (cost-push) shocks play in the economy. Secondly, we introduce exogenous shocks to the fiscal and monetary policy rules thereby increasing the total number of shocks in the model from 1 to 7.[5]

In a nutshell, the model comprises of four sectors namely: households, firms, the government, and the central bank. The households own the firms and they invest capital and labor hours into them. The firms in turn use the capital and labor to produce goods which are then

[5] Having 7 shocks instead of 1 means we can use up to 7 data series for estimation and this allows us to estimate the multiple policy rules that we have using all relevant data that is required for a reliable estimation.

consumed in the form of private consumption, investment, and public goods. The government provides the public goods and finances them by taxing consumption goods, and incomes earned by the households. The government also uses its public spending and taxation authority for the purposes of macroeconomic stabilization by way of discretionary fiscal policy. Lastly, the central bank conducts monetary policy by controlling the nominal interest rate in response to inflation and business cycles. The details on how each sector operates are as follows.

3.1. Households

Our model economy is populated by a continuum of identical infinitely lived households $i \in (0,1)$. Each household maximizes expected lifetime utility which we express as

$$E_0 \sum_{t=0}^{\infty} \beta^t U_{i,t}(c_{i,t}, m_{i,t}, n_{i,t})$$

where E_t is the conditional expectations operator given information available to the household at time t, $\beta \in (0,1)$ denotes a discount factor common to all households, and $U_{i,t}$ denotes household i's period utility function whose arguments consist of a consumption bundle $c_{i,t}$, labor hours $n_{i,t}$, and real money balances $m_{i,t}$. Here $c_{i,t}$ is defined as a Dixit-Stiglitz composite good that aggregates a variety of goods $j \in [0,1]$ that the household consumes. Thus

$$c_{i,t} = \left[\int_0^1 \left(c_{i,t}(j)\right)^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}}$$

where $c_{i,t}(j)$ denotes a differentiated consumption good j, and $\epsilon > 1$ is the elasticity of substitution across the varieties.

With regards to $U_{i,t}$, we assume a constant relative risk aversion (CRRA) utility function which we specify as follows.

$$U_{i,t}(c_{i,t}, m_{i,t}, n_{,it}) = \begin{cases} \dfrac{e^{a_{i,t}}\, c_{i,t}^{1-\sigma}}{1-\sigma} - \lambda_n \dfrac{n_{i,t}^{1+\eta}}{1+\eta} + \lambda_m \dfrac{m_{i,t}^{1-\mu}}{1-\mu} & for\ \sigma, \mu \neq 1 \\ e^{a_{i,t}} \ln(c_{i,t}) - \lambda_n \dfrac{n_{i,t}^{1+\eta}}{1+\eta} + \lambda_m \ln(m_{i,t}) & for\ \sigma, \mu = 1 \end{cases}$$

where σ is the CRRA parameter, η is the inverse Frisch elasticity of labor supply, μ is a parameter measuring the elasticity for real money balances, λ_n and λ_m are the respective preference parameters for work hours and real money balances, and $a_{i,t}$ denotes time varying consumption preferences of the households. We further assume that $a_{i,t}$ follows stationary first order autoregressive process

$$a_{i,t} = \rho_a a_{i,t-1} + \varepsilon_{ai,t} \qquad \varepsilon_{ai,t} \sim N(0, \sigma_a^2) \qquad (1.1)$$

Since households own the firms, they allocate part of their income for investment $i_{i,t}$ and hence accumulate capital $k_{i,t}$ for use in the firm's production process. Therefore, for a given capital depreciation rate $\delta \in (0,1)$, the amount of capital owned by each household is assumed to evolve according to the standard law of motion for capital

$$k_{i,t} = i_{i,t} + (1-\delta)k_{i,t-1} \qquad (1.2)$$

As the household allocates its resources to maximize utility, it is bound by a budget constraint that restricts its expenditures to its disposable income and does not allow borrowing of additional resources. This budget constraint is given by

$$\left(1-\tau_t^y\right)\left(w_t n_{i,t}+r_t^k k_{i,t-1}+d_{i,t}\right)+\Pi_t^{-1}\left(R_t b_{i,t}+m_{i,t-1}\right)$$
$$=(1+\tau_t^c)c_{i,t}+i_{i,t}+b_{i,t+1}+m_{i,t} \tag{1.3}$$

where τ_t^y and τ_t^c represent the tax rates for household incomes and consumption respectively, r_t^k is the rental rate of capital, w_t is the hourly wage rate, $d_{i,t}$ are dividend payments from the firms, $b_{i,t}$ is the amount of government bonds held at the beginning of period *t* paying R_t in gross nominal return, and $\Pi_t \equiv P_t/P_{t-1}$ is the gross inflation rate. Here all variables apart from the tax rates are expressed in real terms by dividing their nominal counterparts with the price index, P_t.

The solution to the household problem satisfies the first order conditions (FOCs) in equations (1.4) - (1.7) below in addition to the budget constraint (1.3) above. These equations comprise of the consumption Euler equation (1.4), and the optimality conditions for labor hours (1.5), for real money balances (1.6) and for bond holdings (1.7).

$$\frac{a_{i,t}\ c_{i,t}^{-\sigma}}{1+\tau_t^c}=\beta E_t\left[\frac{a_{i,t+1}\ c_{i,t+1}^{-\sigma}}{1+\tau_{t+1}^c}\left\{\left(1-\tau_{t+1}^y\right)r_{t+1}+1-\delta\right\}\right] \tag{1.4}$$

$$\lambda_n n_{i,t}^{\eta} c_{i,t}^{\sigma}=a_{i,t}\left(\frac{1-\tau_t^y}{1+\tau_t^c}\right)w_t \tag{1.5}$$

$$\frac{a_{i,t}\ c_{i,t}^{-\sigma}}{1+\tau_t^c}-\lambda_m m_{i,t}^{-\mu}=\beta E\left[\frac{a_{i,t+1}\ c_{i,t+1}^{-\sigma}}{1+\tau_{t+1}^c}\ \frac{1}{\Pi_{t+1}}\right] \tag{1.6}$$

$$\frac{a_t\ c_{i,t}^{-\sigma}}{1+\tau_t^c}=\beta E\left[\frac{a_{i,t+1}\ c_{i,t+1}^{-\sigma}}{1+\tau_{t+1}^c}\ \frac{R_{t+1}}{\Pi_{t+1}}\right] \tag{1.7}$$

3.2. Firms

In this economy there are two types of firms. The first type consists of a continuum of monopolistic firms $j \in [0,1]$ that produce differentiated intermediate goods $y_t(j)$. The second type of firms operate in a perfectly competitive market and use $y_t(j)$ as inputs to produce the final composite good y_t.

3.2.1. Final good producing firm

The final good producing firm uses the differentiated goods $y_t(j)$ as the only inputs for producing the composite final good y_t. As such, the production function of y_t also takes the form of an aggregator function. Specifically, y_t is produced by the same Dixit-Stigliz aggregator function as $c_{i,t}$. Therefore we have

$$y_t = \left(\int_0^1 \{y_{j,t}\}^{\frac{\epsilon-1}{\epsilon}} \partial j\right)^{\frac{\epsilon}{\epsilon-1}}$$

Given this production technology, the firm's problem is to choose a combination of $y_t(j)$ that minimizes its total production costs

$$\int_0^1 P_t(j)\, y_t(j)\, \partial j$$

where $P_t(j)$ denotes the price for input $y_t(j)$. The first-order condition from this problem yields the optimal levels of $y_t(j)$ as functions of their respective prices $P_t(j)$, the aggregate price P_t and aggregate demand y_t. Specifically, the final good firm chooses the amount of good *j* to be used as inputs according to

$$y_t(\mathrm{j}) = \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon} y_t$$

where $$P_t = \left(\int_0^1 \{P_t(j)\}^{1-\epsilon}\, \partial j\right)^{\frac{1}{1-\epsilon}}$$

Furthermore, in equilibrium the level of y_t produced must satisfy all the demand from the households and the government. Therefore, given the aggregate demand for consumption $c_t \equiv \int_0^1 c_{i,t}\,\partial i$, the aggregate demand for investment $i_t \equiv \int_0^1 i_{i,t}\,\partial i$, and the demand for public goods g_t, the goods market equilibrium satisfies

$$y_t = c_t + i_t + g_t \tag{1.8}$$

3.2.2. Intermediate good producing firms

Unlike the final good firms, the firms producing the intermediate good possess some monopolistic power. This allows each firm j to set its price $P_t(j)$ at a markup above the marginal cost MC_t and hence generate some positive profit $d_t(j)$. However when setting the price, the intermediate good firm faces some inflexibilities in the form of Calvo price stickiness. Specifically, every period the firm faces a probability $\theta \in (0,1)$ that it fails to reset its price. Given this setting, the firm faces a two stage problem, one involving how to choose factor inputs, and the other involving how to set the price for its output.

Factor input choice

In the first stage, the firm chooses the level of capital $k_{t-1}(j)$ and labor hours $n_t(j)$ that minimize production costs $(w_t n_t(j) + r_t k_{t-1}(j))$ subject to its production technology. This production technology is assumed to be of a Cobb-Douglas form and is given by

$$y_t(j) = e^{z_t}\{\,k_{t-1}(j)\}^{\alpha}\,\{n_t(j)\}^{1-\alpha} \tag{1.9}$$

$$z_t = \rho_z z_{t-1} + \varepsilon_t^z \tag{1.10}$$

where z_t is total factor productivity (TFP) that follows an AR(1) process with a persistence parameter $\rho_z \in [0,1)$ and a shock component $\varepsilon_t^z \sim N(0, \sigma_z^2)$, and $\alpha \in [0,1]$ is the capital share of income. The first order conditions for this problem give the labor and capital demand conditions

$$w_t = (1-\alpha)\, e^{z_t} \left(\frac{k_{t-1}(j)}{n_t(j)}\right)^{\alpha} \tag{1.11}$$

$$r_t = \alpha\, e^{z_t} \left(\frac{k_{t-1}(j)}{n_t(j)}\right)^{\alpha-1} \tag{1.12}$$

Given these input prices the nominal cost function $\mathrm{C}_t(y_t(j))$ becomes

$$\mathrm{C}_t(y_t(j)) = MC_t y_{j,t}$$

where $MC_t \equiv e^{z_t} \left(\frac{r_t}{\alpha}\right)^{\alpha} \left(\frac{w_t}{1-\alpha}\right)^{1-\alpha}$ is the nominal marginal cost common to all firms j.

Pricing decision

Having chosen the optimal levels of $k_{t-1}(j)$ and $n_t(j)$, the firm that is able to adjust its price sets the new price $P_t^*(j)$ which maximizes profits expected to be realized in the next *s* periods that this price is expected to be maintained. Thus $P_t^*(j)$ is chosen by solving

$$\max_{P_t^*(j)} \; E_t \sum_{s=0}^{\infty} \theta^s\, \Omega_{t,t+s}\, \left\{P_t^*(j)\, y_{t+s}(j) - e^{\psi_{t+s}}\, \mathrm{C}_{t+s}(y_{t+s}(j))\right\}$$

subject to the demand for $y_{t+s}(j)$ from the final goods firm. Here, $\Omega_{t,t+s} \equiv \beta^s \left(\frac{c_{t+s}}{c_t}\right)^{-\sigma} \left(\frac{P_{t+s}}{P_t}\right)^{-1} \left(\frac{1+\tau_t^c}{1+\tau_{t+1}^c}\right)$ is the firm's discount factor of period *t*+*s* as at period t, and ψ_t is a time varying price markup (or "cost-push") that is common to all intermediate goods producers and follows a stationary AR(1) process

$$\psi_t = \rho_\psi \psi_{t-1} + \varepsilon_t^\psi \qquad\qquad \varepsilon_{\psi,t} \sim N(0, \sigma_\psi^2) \tag{1.13}$$

The solution to this problem satisfies the first order condition

$$E_t \sum_{s=0}^{\infty} \theta^s \, \Omega_{t,t+s} \; \Xi_{t+s}^{-\epsilon} \, y_{t+s} \left\{ \Xi_t - \Lambda \, e^{\psi_{t+s}} \, mc_{t+s} \, \Pi_{t,t+s} \right\} = 0 \tag{1.14}$$

where $\Xi_{t+s} \equiv P_t^*(j) \,/ P_{t+s}$, $\Lambda \equiv \epsilon/(\epsilon - 1)$ is the desired price markup over marginal cost,[6] $mc_{t+s} \equiv \; MC_{t+s}/P_{t+s}$ denotes the real marginal cost in period $t+s$, and $\Pi_{t,t+s} \equiv P_{t+s}/P_t$ is gross inflation between periods t and $t+s$.

Price dynamics

As demonstrated in Gali (2008), this setting implies that aggregate prices will evolve according to the process

$$P_t^{1-\epsilon} = \theta \, P_{t-1}^{1-\epsilon} + (1-\theta) \left(P_t^*(j)\right)^{1-\epsilon}$$

or

$$\Pi_t^{1-\epsilon} = \theta \; + (1-\theta) \, (\Xi_t \, \Pi_t)^{1-\epsilon} \tag{1.15}$$

3.3. The Government

The government is responsible for the provision of public goods, g_t, which it funds by imposing taxes on consumption goods and household incomes. The government also issues interest bearing bonds b_t and has access to a stock of money m_t. As such, the government's budget constraint is as expressed in equation (1.16) below.

$$b_{t+1} + m_t + \tau_t^c c_t + \tau_t^y \left(w_t n_t + r_t^k k_{t-1} + d_t \right) = g_t + \frac{P_{t-1}}{P_t} \left(R_t b_t + m_{i,t-1} \right) \tag{1.16}$$

[6] See Gali (2008)

Furthermore, in addition to providing public services, the government also conducts discretionary fiscal policy in response to output fluctuations. It does so by targeting g_t, τ_t^c, and τ_t^y using policy rules (1.17) – (1.19) below.

$$\tilde{g}_t = \rho_g \tilde{g}_{t-1} + \gamma_y^g \tilde{y}_t + \varepsilon_t^g \tag{1.17}$$

$$\tilde{\tau}_t^c = \rho_\tau^c \tilde{\tau}_{t-1}^c + \gamma_y^c \tilde{y}_t + \varepsilon_t^{\tau c} \tag{1.18}$$

$$\tilde{\tau}_t^y = \rho_\tau^y \tilde{\tau}_{t-1}^y + \gamma_y^y \tilde{y}_t + \varepsilon_t^{\tau y} \tag{1.19}$$

where $\tilde{g}_t$, $\tilde{\tau}_t^c$, and $\tilde{\tau}_t^y$ indicate log deviations of g_t, τ_t^c, and τ_t^y from their respective steady state values, parameters ρ_g, ρ_τ^c, and ρ_τ^y are the smoothing parameters for g_t, τ_t^c, and τ_t^y respectively, parameters γ_y^g, γ_y^c, and γ_y^y are the policy feedback coefficients with respect to output fluctuations, and $\varepsilon_t^g, \varepsilon_t^{\tau c}$, and $\varepsilon_t^{\tau y}$ are the exogenous shocks to the corresponding policies, each having a zero mean and the respective standard deviations, $\sigma_g, \sigma_{\tau c}$, and , $\sigma_{\tau y}$.

3.4 Central Bank

Lastly, the central bank is responsible for maintaining stability of prices and output through monetary policy. It does so by targeting nominal interest rates in reaction to deviations of the inflation rate and output growth from their desired values. Specifically, the bank employs a Taylor type monetary policy rule given by

$$\ln\left(\frac{R_t}{R}\right) = \ln\left(\left\{\frac{R_{t-1}}{R}\right\}^{\rho_R} \left\{\left(\frac{\Pi_t}{\Pi}\right)^{\phi_\pi} \left(y_t^g\right)^{\phi_y}\right\}^{1-\rho_R} e^{u_t}\right)$$

or

$$\tilde{r}_t = \rho_R \, \tilde{r}_{t-1} + (1-\rho_R)\left(\phi_\pi \tilde{\pi}_t + \phi_y \tilde{y}_t^g\right) + u_t \tag{1.20}$$

where $y_t^g \equiv y_t/y_{t-1}$ is output growth, $\tilde{y}_t^g \equiv \ln(y_t^g)$, $\tilde{r}_t$ is the log deviation of nominal interest rate from its steady state value, $\tilde{\pi}_t$ is the net inflation rate, ϕ_π , $\phi_y \geq 0$ are the parameters measuring the responsiveness of interest rate to changes in inflation and output respectively, $\rho_R \in [0, 1]$ is the interest rate smoothing parameter and u_t is an exogenous component of monetary policy. u_t itself is assumed to follow a stationary AR (1) process

$$u_t = \rho_u u_{t-1} + \varepsilon_t^R \qquad \varepsilon_{R,t} \sim N(0, \sigma_\varepsilon^2) \tag{1.21}$$

As such ε_t^R represents a monetary policy shock.

3.5 Model equilibrium

Model equilibrium requires that all factor input prices and the price of goods adjust in such a way that all markets clear and all agents and entities in the model maximize their respective objectives. In our model this is achieved when equations 1.1 through 1.21 above are all satisfied. These 21 equations determine the short-run paths of the 21 endogenous variables (y_t, c_t, i_t, k_t, n_t, $z_t, a_t, \psi_t, r_t, w_t, \Pi_t, \Xi_t, mc_t, m_t, b_t, d_t, R_t, g_t, \tau_t^c, \tau_t^{in}$, and u_t ,) given the state of the stochastic shocks $\varepsilon_t^z, \varepsilon_t^a, \varepsilon_t^\psi, \varepsilon_t^R, \varepsilon_t^g, \varepsilon_t^{\tau y}$, and $\varepsilon_t^{\tau c}$.

It should be noted that the first order conditions for the households and the intermediate goods firms also apply at the aggregate level. This is due to the identical nature of the households on one hand, and on the other the fact that all intermediate good producing firms use the same constant returns to scale (CRS) production technology. Thus for the equilibrium of the model we simply proceed by dropping "*i*" and "*j*" in our equations.

4. Estimation

DSGE models like ours which are characterized by high dimensional non-linearities and stochasticity bring with them computational complexities that require some transformation of the model to a more tractable version. This is typically done by log-linearizing the model around its steady state after which the computational burden during solving the model is significantly lowered. For our case, a first order log-linear approximation of the model is done with the help of the MATLAB based Dynare 4.5.6 software which uses perturbation methods to compute the approximate decision rules and transition equations of a model.

4.1. Data description

We estimate the model using quarterly data on 7 variables comprising of private consumption, private investment, consumer prices, government spending, nominal interest rates, consumption tax revenue, and income tax revenue. Our sample period is 2008:Q3 to 2017:Q2. However, data for private consumption and private investment are available at annual frequency only and therefore we get their quarterly estimates by means of interpolation. Specifically, we employ the Chow-Lin method of interpolation in which we use imports and private debt as indicator variables for private consumption and private investment respectively.

The aforementioned data is sourced from different databases that include the IMF's international financial statistics (IFS), the World Bank's world development indicators (WDIs), The Reserve Bank of Malawi (RBM) statistics, and the National Statistical Office of Malawi (NSO) statistical reports. Table 1 below provides a summary of the description of each variable and the database from which it is sourced.

Table 1: Data description and sources

Variable	Description	Source
consumption (c_t)	final consumption expenditure by the private sector.[7]	IFS, NSO
investment (i_t)	gross fixed capital formation by the private sector.[8]	WDI, RBM
govt. spending (g_t)	total government expenditures	IFS
prices (P_t)	consumer price index (CPI)	IFS
interest rate (R_t)	3 month treasury bill rate	IFS
consumption tax revenue	taxes on goods and services	NSO
income tax revenue	taxes on incomes and profits	NSO

4.2 Choice of priors

All parameters in this the model except for σ (the CRRA parameter) and η (inverse of Frisch labor supply elasticity) are estimated and thus require that prior distributions be provided. We obtain these priors from related literature and from sample moments from available data. Fairly loose priors are used in order to accommodate the possibility that the true parameters for the Malawi economy may significantly deviate from the values that are commonly presented in literature given that most of this literature focuses on more advanced economies as opposed to less advanced ones like Malawi. The prior distributions for all parameters and their sources are summarized in table 2 below.

[7] Annual private consumption data is obtained from IFS while the annual and quarterly imports data used for interpolation is obtained from NSO statistical reports.

[8] Annual private investment data is obtained from WDIs while the annual and quarterly private debt data used for interpolation are obtained from RBM statistics.

Table 2: Prior distributions for parameters

Parameter		Prior density	Prior mean	Prior std dev	Source
discount factor:	β	beta	0.85	0.05	average treasury bill rate
labor preference parameter:	λ_n	gamma	1	0.5	arbitrarily set to 1
money preference parameter	λ_m	gamma	1	0.5	arbitrarily set to 1
CRRA parameter :	σ	fixed	1	0	special case of CRRA
Inverse of Frisch labor supply elasticity :	η	fixed	1	0	unitary Frisch elasticity of labor supply
inverse elasticity of substitution for real money balances :	μ	gamma	2.38	0.5	set to match estimated interest-rate semi elasticity of money demand in Malawi
capital share of income :	α	beta	0.3	0.03	common in related literature
capital depreciation rate :	δ	beta	0.025	0.01	common in DSGE literature
Calvo pricing parameter	θ	beta	0.5	0.05	arbitrarily set
price elasticity of demand :	ϵ	gamma	6	1	Gali (2008)
persistence of productivity :	ρ_z	beta	0.5	0.25	Smets and Wouters (2007)
persistence of consumption preferences :	ρ_a	beta	0.5	0.25	
persistence of price markups	ρ_ψ	beta	0.5	0.25	
Parameters for policy rules					
Taylor rule inflation coefficient:	ϕ_π	gamma	1.5	0.5	Taylor's recommendation
Taylor rule coefficient on output growth :	ϕ_y	gamma	0.5	0.5	Taylor's recommendation
interest rate smoothing parameter	ρ_R	beta	0.5	0.25	arbitrarily set
monetary policy shock persistence parameter	ρ_u	beta	0.5	0.25	arbitrarily set
government spending smoothing parameter :	ρ_g	beta	0.5	0.25	arbitrarily set
spending rule output responsiveness :	γ_y^g	gamma	0.1	0.1	set within ranges in related literature
consumption tax smoothing parameter :	ρ_τ^c	beta	0.5	0.25	arbitrarily set
consumption tax responsiveness to output :	γ_y^c	gamma	0.1	0.1	Set to within ranges in related literature
income tax smoothing parameter :	ρ_τ^y	beta	0.5	0.25	Set arbitrarily
income tax responsiveness to output:	γ_y^y	gamma	0.1	0.1	Set to within ranges in related literature
Shocks (standard deviations)					
$\sigma_z, \sigma_a, \sigma_\psi, \sigma_R, \sigma_g, \sigma_{\tau c}, \sigma_{\tau in}$		inverse-gamma	0.1	5	harmonized uninformative priors for all shocks

4.3 Estimation Results

As we've already outlined, the main tasks in this study 3 fold and include: 1) estimation of policy feedback rules for the nominal interest rate, government spending, income taxes, and consumption taxes, 2) analysis of the effects of policy shocks on key macroeconomic variables, and 3) analysis of the relative influences of the policy shocks, productivity shocks, consumer preference shocks, and price mark-up shocks as determinants of price movements and business cycles in Malawi. This section provides the answers to these questions. We do this by making inferences from the posterior estimates of the model parameters, the estimated impulse response functions, and the estimated variance decompositions of key variables. However before making such inferences, we make sure that our estimated model is stable and our parameter estimates have converged to their final values. For this we make use of convergence diagnostics and trace plots presented in appendix 2 which show that for just 300,000 iterations our model converges very well.

4.3.1. Fiscal and monetary policy rules

The posterior distributions for the model parameters are presented in table 4.3 below. The table shows the parameters' posterior means and their respective 90% highest posterior densities (HPDs) which we use as our credible intervals. Looking at the posterior means of the policy parameters, we can now write our estimated fiscal policy and monetary policy feedback rules as follows.

Taylor rule $$\tilde{r}_t = 0.3989\,\tilde{r}_{t-1} + 0.6011(1.2101\,\tilde{\pi}_t + 0.2427\,\tilde{y}_t)$$

spending rule: $$\tilde{g}_t = 0.1688\,\tilde{g}_{t-1} + 0.1238\,\tilde{y}_t$$

consumption tax rule : $$\tilde{\tau}_t^c = 0.3506\,\tilde{\tau}_{t-1}^c + 0.0685\,\tilde{y}_t$$

income tax rule $$\tilde{\tau}_t^y = 0.173\,\tilde{\tau}_{t-1}^y + 0.0975\,\tilde{y}_t$$

Monetary policy rules

The estimated Taylor rule shows that monetary policy in Malawi reacts to both inflation and output. With regards to inflation, the central bank operates within the Taylor principle by raising the nominal interest rate by 1.21 percentage points for every 1 percentage point increase in inflation. The reaction to output fluctuations on the other hand is much more moderate than Taylor's recommendation of $\phi_y = 0.5$. Specifically, our estimates show that a 1 percentage point reduction in output growth induces an interest rate cut of about 0.24 percentage points. Lastly the central bank also exercises some interest rate smoothing by having about 40 percent ($\rho_R \approx 0.4$) of the adjustment in the nominal interest rate depend on its lagged value.

Fiscal policy rules

All three fiscal rules that we estimate show that fiscal policy also reacts to output fluctuations rather modestly. The fiscal authorities react to a 1 percentage drop in output by increasing government spending by $\gamma_y^g = 0.12$ percent and by cutting the consumption tax rate and the income tax rate by only 0.0685 and 0.0975 percentage points respectively. All three reactions here are much more moderate compared to the reaction of monetary policy seen above. This suggests that when it comes to the issue of macroeconomic stabilization in Malawi, monetary policy takes the lead over fiscal policy.

Lastly the degree of inertia in all three fiscal policy rules is also on the lower side particularly for the government spending rule which has $\rho_g \approx 0.169$. Consumption and income taxes also have low policy inertias at $\rho_\tau^c \approx 0.350$ and $\rho_\tau^y \approx 0.173$ respectively although unsurprisingly higher than that of government spending.

Table 3: Parameter estimates

Parameter		Prior			Posterior	
		density	***mean***	***std. dev***	***mean***	***90% HPD interval***
discount factor:	β	beta	0.85	0.05	0.8776	[0.8545 , 0.9004]
labor preference parameter:	λ_n	gamma	1	0.5	0.8801	[0.7291 , 1.0254]
money preference parameter :	λ_m	gamma	1	0.5	0.9987	[0.8335 , 1.1591]
Parameter related to elasticity for money demand :	μ	gamma	2.38	0.5	2.3669	[1.5572 , 3.1666]
capital share of income :	α	beta	0.3	0.02	0.3127	[0.2778 , 0.3471]
depreciation rate of capital :	δ	beta	0.025	0.02	0.2832	[0.2347 , 0.3443]
Calvo pricing parameter :	θ	beta	0.5	0.2	0.4352	[0.3657 , 0.5062]
price elasticity of demand :	ϵ	gamma	6	2	6.9394	[5.2843 , 8.5017]
persistence of productivity:	ρ_z	beta	0.5	0.25	0.5777	[0.3951 , 0.7689]
persistence of consumption preferences :	ρ_a	beta	0.5	0.25	0.8063	[0.6835 , 0.9401]
persistence of price markups :	ρ_ψ	beta	0.5	0.25	0.7526	[0.5695 , 0.9473]
Parameters for policy rules						
Taylor rule coefficient on inflation :	ϕ_π	gamma	1.5	0.5	1.2101	[1.0342 , 1.3909]
Taylor rule coefficient on output growth :	ϕ_y	gamma	0.5	0.5	0.2427	[0.0856 , 0.3952]
interest rate smoothing parameter	ρ_R	beta	0.5	0.25	0.3989	[0.3113 , 0.4849]
monetary policy shock persistence parameter	ρ_u	beta	0.5	0.25	0.0265	[0.0004 , 0.0533]
government spending smoothing parameter :	ρ_g	beta	0.5	0.25	0.1688	[0.0027 , 0.3238]
spending rule output responsiveness :	γ_y^g	gamma	0.1	0.1	0.1238	[0.0372 , 0.2055]
consumption tax smoothing parameter :	ρ_τ^c	beta	0.5	0.25	0.3506	[0.0357 , 0.6215]
consumption tax responsiveness to output :	γ_y^c	gamma	0.1	0.1	0.0685	[0.0170 , 0.1173]
income tax smoothing parameter :	ρ_τ^{in}	beta	0.5	0.25	0.1730	[0.0056 , 0.3209]
income tax responsiveness to output :	γ_y^{in}	gamma	0.1	0.1	0.0975	[0.0244 , 0.1673]

Shocks (standard deviations)

productivity :	σ_z	inverse gamma	0.05	5	0.0516	[0.0390 , 0.0639]
preference :	σ_a	inverse gamma	0.05	5	0.0422	[0.0302 , 0.0540]
cost-push :	σ_ψ	inverse gamma	0.05	5	0.0523	[0.0266 , 0.0780]
monetary policy :	σ_R	inverse gamma	0.05	5	0.0641	[0.0480 , 0.0794]
govt. spending :	σ_g	inverse gamma	0.05	5	0.0155	[0.0125 , 0.0184]
consumption tax :	$\sigma_{\tau c}$	inverse gamma	0.05	5	0.0150	[0.0123 , 0.0176]
income :	$\sigma_{\tau y}$	inverse gamma	0.05	5	0.0204	[0.0166 , 0.0242]

4.3.2. Macroeconomic impact of fiscal and monetary policy

Having estimated the fiscal and monetary policy rules, our next task is to analyze the impact of these policies on the key macroeconomic variables. We do so by examining the responses of selected variables to our estimated monetary policy and fiscal policy shocks. For our purposes, we focus on the impulse responses of output, consumption, investment, and inflation for a given monetary or fiscal policy shock of 1 standard deviation in magnitude. These impulse responses are presented in figures 4.1 to 4.4. Additionally, we also present the model's implied steady state values which happen to serve as the reference points for our impulse responses. These are shown in table 4 below.[9]

[9] For the tax rates and government spending share of total output, their steady state values are set as their data averages. For the rest of the variables, theirs are derived analytically as functions of the model parameters by assuming time invariance of all variables.

Table 4: Model implied steady state values

Variable	*Steady state value*	*Variable*	*Steady state value*
output, y_t	0.6291	nominal interest rate, R_t	1.176471
consumption, c_t	0.49591	government spending, g_t	0.119529
investment, i_t	0.013661	income tax rate, τ_t^c	0.19
gross inflation, Π_t	1	consumption tax rate, τ_t^y	0.16

The impact of monetary policy

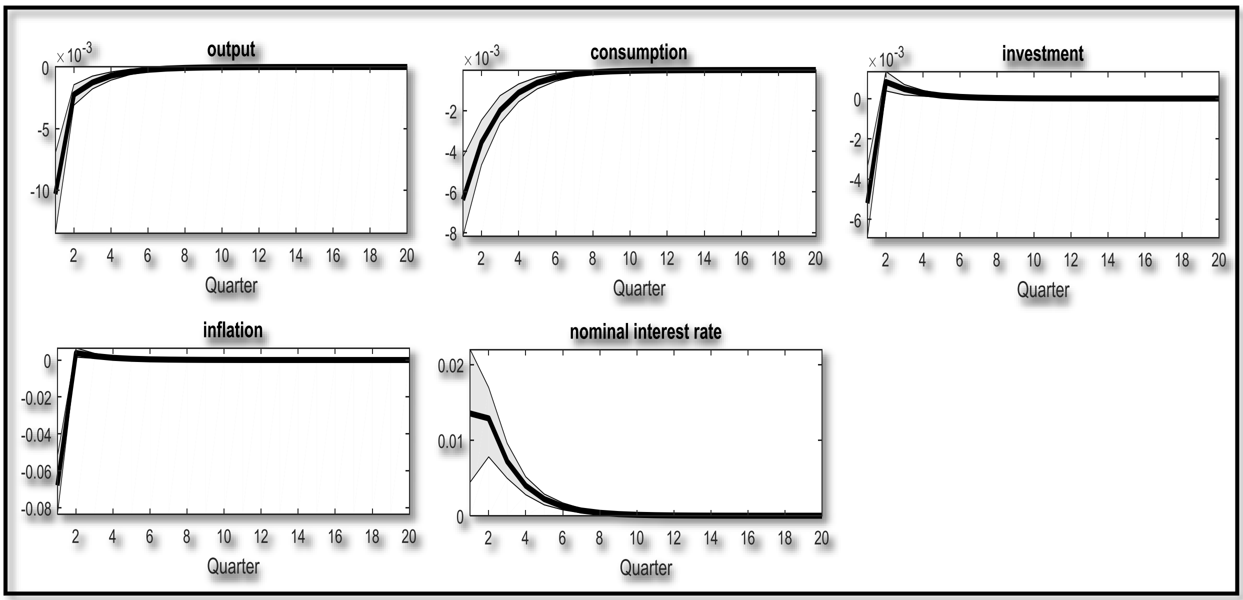
The impulse responses to a monetary policy shock are shown in figure 4.1. Looking at the responses of output, investment, and consumption, we see that monetary policy is not neutral but rather it affects both nominal and real variables. Specifically we see that a 1 standard deviation (0.0641) increase in the nominal interest rate induces an immediate 0.001 percentage point decline in output as both investment and consumption also decline by 0.005 and 0.006 percentage points respectively. The decline of consumption and investment comes as a result of a rise in the real interest rate which ultimately makes savings more attractive while simultaneously making debt financed investment and consumption less so.

The impulse responses further show that the interest rate shock also leads to a temporary reduction in inflation of about 7 basis points. In contrast to some VAR based studies done on Malawi that found the so called "price puzzle",[10] this result satisfies the theoretical predictions regarding the impact of monetary policy on inflation. It should be noted though that while we do not encounter the price puzzle in our model, the dynamics of inflation and investment indicate an

[10] see Ngalawa (2010) and Mangani (2012)

immediate return to their steady state levels within a quarter following the shock. This is not an uncommon feature for models with limited sources of nominal rigidities but nevertheless it is an issue worth exploring further.

Figure 4.1: Impulse responses to a monetary policy shock

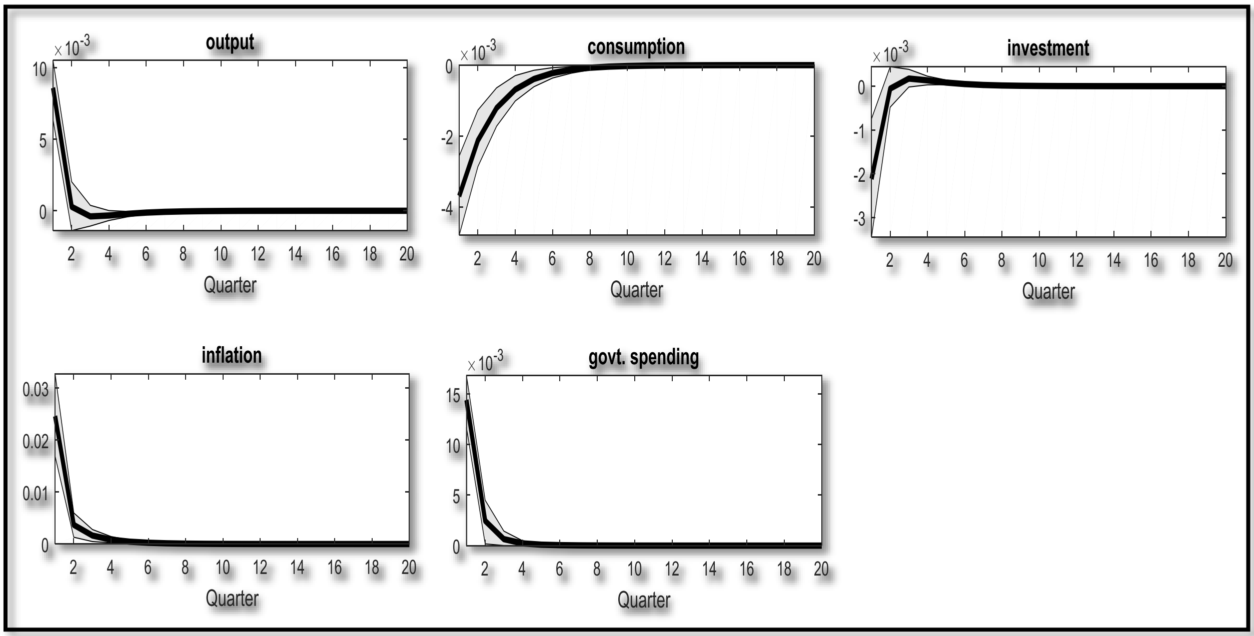


Note: The thick lines are the mean responses and the shaded areas are 90th percentile confidence bands.

The impact of fiscal policy

The dynamic effects of shocks to government spending, consumption taxes and income taxes are shown in figures 4.2 through 4.4 below. As figure 4.2 shows, an expansionary government spending shock of 1 standard deviation size raises output and prices by 0.8 percentage points and 2.5 percentage points respectively. The increase in output occurs in spite of a crowding out of both investment and private consumption. Here it is important to note that, while the government's ability to crowd out of private investment is theoretically established and empirically well documented, the crowding out effect on private consumption is still in debate. One of the proposed explanations is the existence forward looking agents who, following the increase in government spending, anticipate a future tax increase and therefore increase their savings now for consumption smoothing purposes. Furthermore a rise in interest rate (which we observe in our model) following the spending shock provides extra incentive to save while the above-mentioned rise in consumer prices forces households to cut consumption as their budget constraint tightens.

Figure 1: Impulse responses to government spending shock

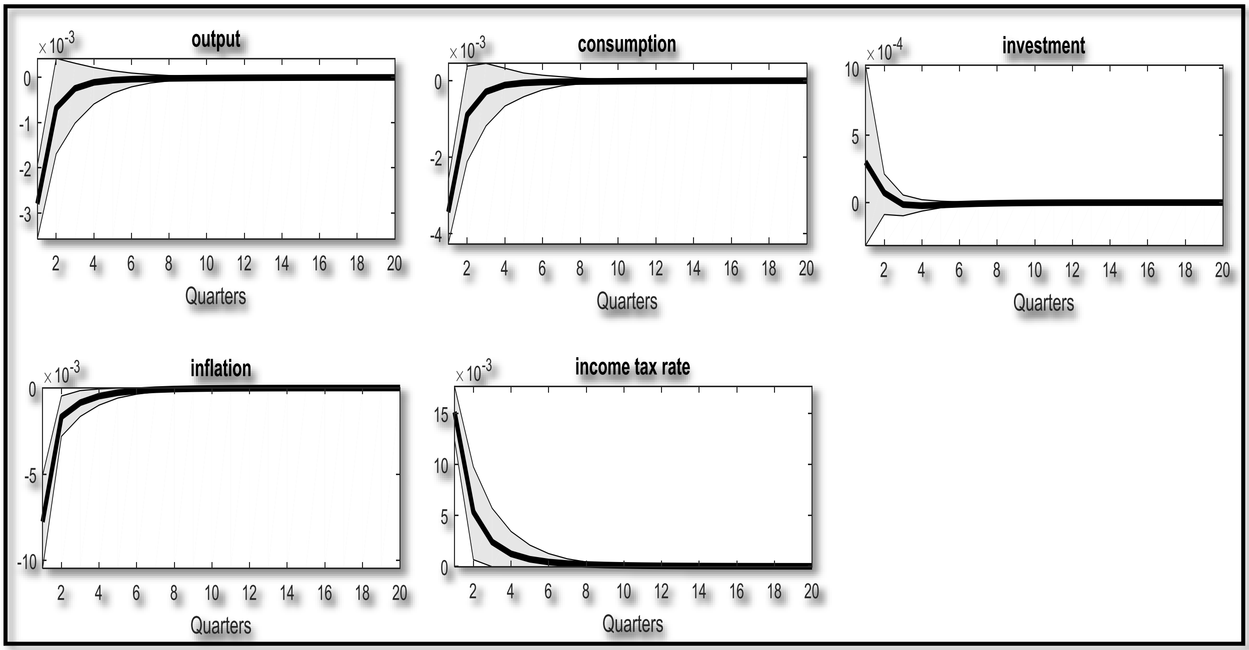


Note: The thick lines are the mean responses and the shaded areas are 90th percentile confidence bands.

With regards to consumption taxes, the effects of a positive shock include a 0.35 percentage reduction in consumption which results into a 0.28 percent decline in output and a 0.79 percent decrease in prices. The reduction in consumption reflects both the income effect and the distortionary nature of consumption taxes as households reallocate resources from consumption to savings. In our model the latter is reflected in the apparent increase in investment.

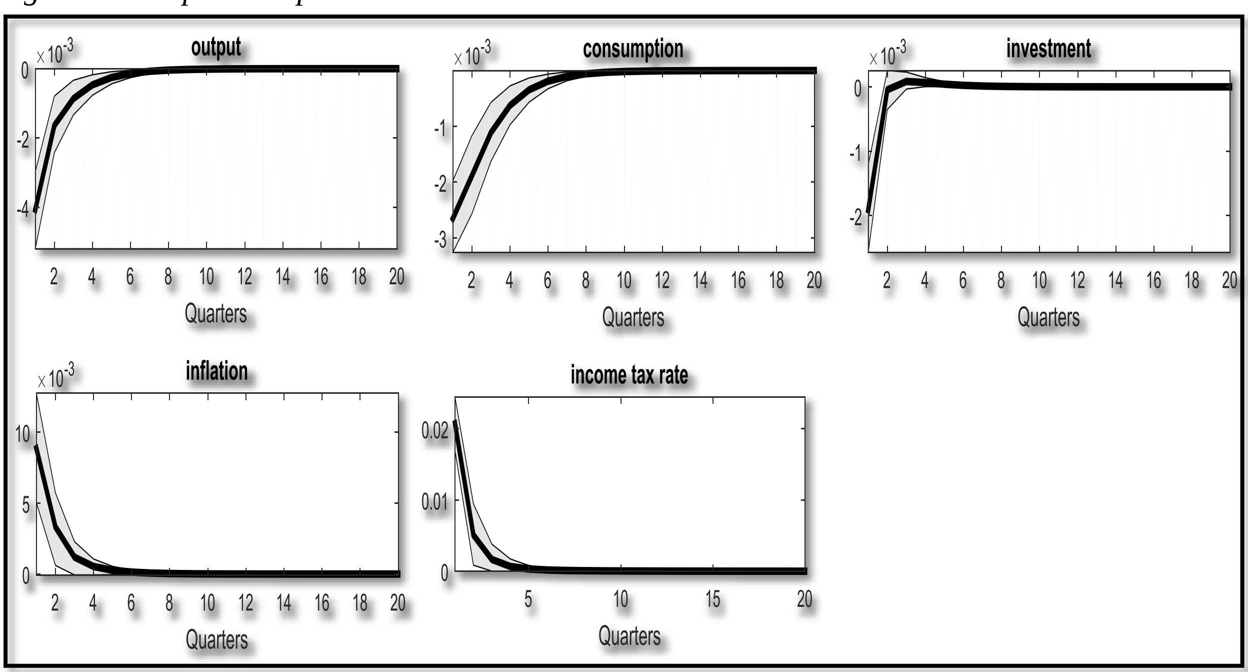
In the case of income taxes, a positive shock to the tax rate also leads to a decrease in consumption, and output but unlike the case of consumption taxes, investment goes down and prices increase. The decline in investment is due to both the income effect of higher taxes and a substitution effect since the taxation of dividends and capital rent creates a disincentive to invest. As for the price increase, this reflects a "cost pass-through" by owners of capital to consumers.

Figure 4.3: Impulse responses to a consumption tax shock



Note: The thick lines are the mean responses and the shaded areas are 90th percentile confidence bands.

Figure 4.4: Impulse responses to an income tax shock

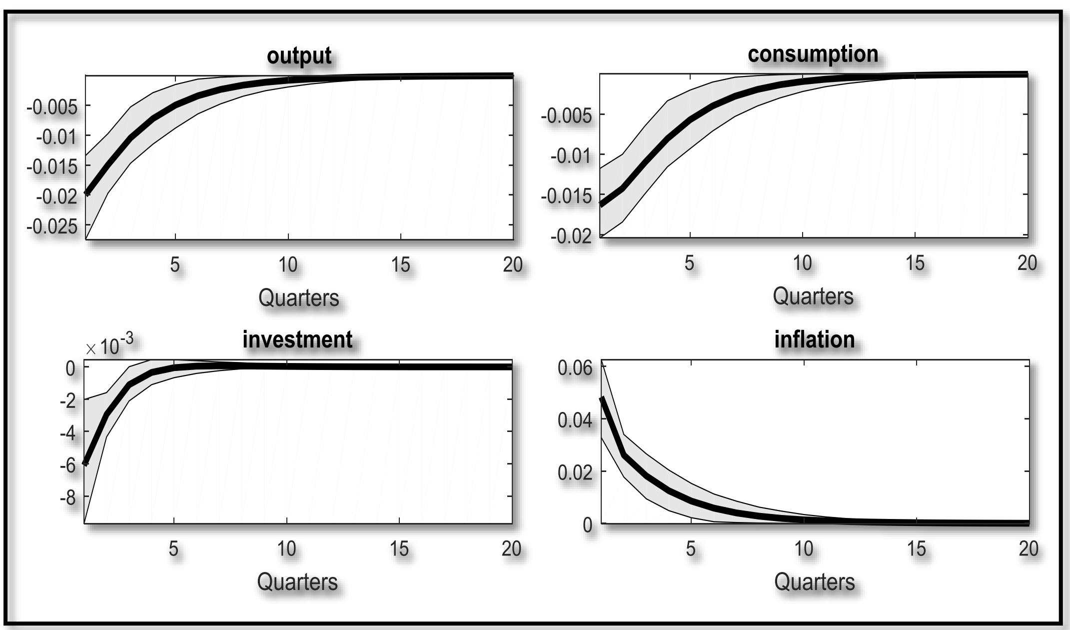


Note: The thick lines are the mean responses and the shaded areas are 90th percentile confidence bands.

The impact of non-policy shocks

Besides fiscal and monetary policy shocks, the other exogenous shocks identified also have significant effects on the macroeconomic variables in the model. The question of how big a role each of them play is answered in the next section when we analyze variance decompositions. For now we focus on the macroeconomic dynamics induced by each of these shocks. In this regard, we find that in the case of negative productivity shocks,[11] output immediately declines by up to 2 percent, and prices jump up 4 percent. Consumption also declines by 1.5 percent which is a smaller drop than that of output thus reflecting the tendency by households to smooth consumption. This is further supported by the response of investment which also drops 0.6 percent.

Figure 4.5: Impulse responses to a negative productivity shock

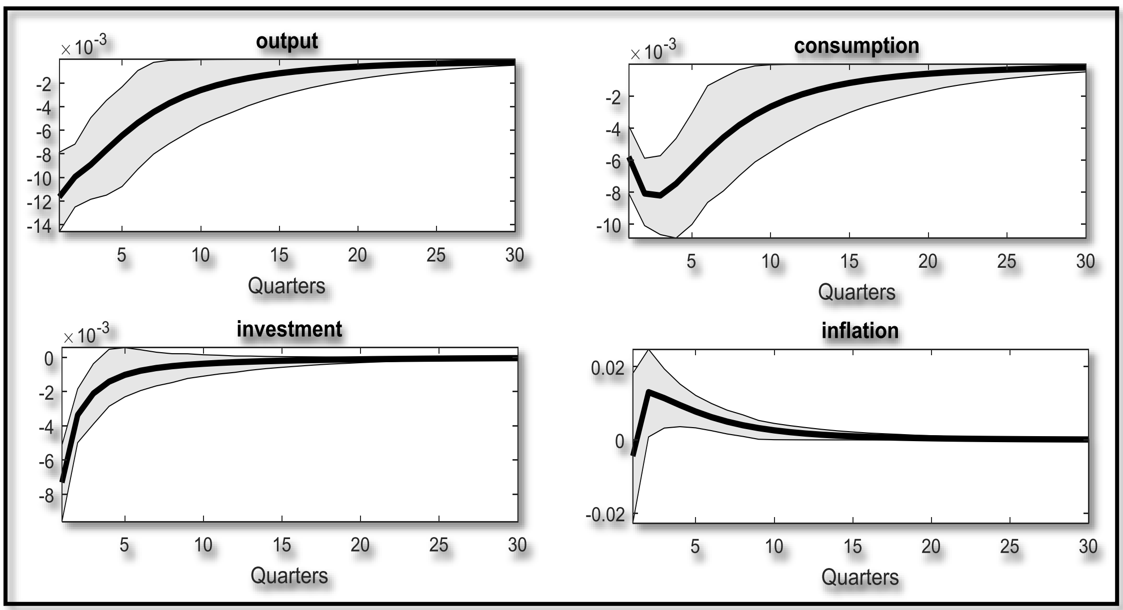


Note: The thick lines are the mean responses and the shaded areas are 90th percentile confidence bands.

[11] Malawi has been increasingly exposed to electric power outages, and negative weather shocks thus making the analysis of the impact of negative productivity shocks rather interesting. Nevertheless, the converse of our findings should hold true for positive shocks since the IRFs are symmetric.

Turning to the other supply side shock – a cost-push shock, we find that a positive shock induces reactions from output, consumption, investment, and prices that are similar to those induced by productivity shocks, but notably by smaller magnitudes. Specifically the contemporaneous decline in output, consumption and investment are 1.2 percent, 0.6 percent, and 0.7 percent respectively. With regards to the impact on prices, the magnitude of the increase is also smaller than that of productivity shocks, peaking at just over 1 percent. All this is points to a dominance of productivity shocks over cost-push shocks when it comes to inducing business cycles, a point that is elucidated in the next section

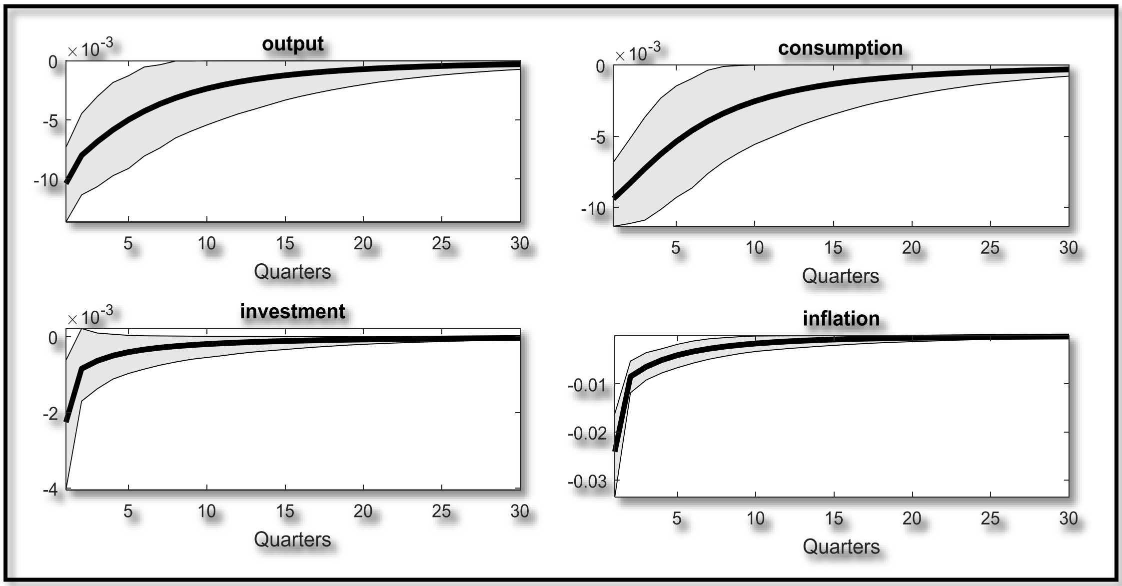
Figure 4.6: Impulse responses to a cost-push shock



Note: The thick lines are the mean responses and the shaded areas are 90th percentile confidence bands.

Last but not least, we look at the impact of consumer preference shocks whose impulse responses are plotted in figure 4.7 below. As the figure shows, a negative preference shock induces downward movements in output, consumption, and investment which reach up to 1 percent, 0.9 percent, and 0.2 percent respectively in the period of the shock. These magnitudes are also smaller than those observed for productivity shocks. The reaction of prices on the other hand differs from the two supply shocks above. Here, as one would expect of a negative demand shock, prices decrease rather than increase. Specifically, the shock results in a 2.5 percent drop in prices which is also a smaller magnitude than that observed in the case of a productivity shock.

Figure 4.7: Impulse responses to a negative consumer preference shock



Note: The thick lines are the mean responses and the shaded areas are 90th percentile confidence bands.

4.3.3. What drives business cycles and prices?

The analysis of impulse responses above points to productivity shocks as being the most important driver of business cycles and prices among the non-policy shocks. This appears to be the case given the relatively bigger effect that this shock has on output, consumption, investment, and prices. In this section we look at how the shocks identified in the model compare to one another in terms of their respective contributions to the fluctuations of output and prices. Table 3 below, which shows the variance decompositions of output, consumption, investment and prices helps us answer this question.

Table 4.3: Variance decomposition of selected variables

Type of shock	***Percentage of variability due to shock***				
	output	*consumption*	*investment*	*inflation*	*interest rate*
productivity	**52.10**	**54.30**	**37.71**	38.17	**64.48**
preference	18.49	22.80	6.62	6.73	12.85
cost-push	17.15	15.64	26.34	3.42	7.05
monetary policy	6.74	4.30	22.25	**45.19**	5.91
government spending	3.86	1.28	3.27	5.10	7.61
consumption tax	0.49	0.89	0.19	0.55	0.86
income tax	1.16	0.80	3.62	0.84	1.24

As we observed in the analysis of the impulse response functions above, the variance decompositions also indicate that consumption, investment, and total output are mainly driven by changes in productivity. Productivity shocks alone account for 54 percent of changes in consumption, 37 percent of changes in investment and 52 percent of fluctuations of total output. Furthermore, productivity shocks also play a significant role in the movements of prices, contributing up to 38 percent of inflation dynamics although monetary policy has a more significant role.

The importance of preference shocks to the fluctuations of total output is found to be about 18 percent, mostly owing to the 22 percent contribution it makes to the variance of household consumption. The last shock playing a sizable role in output fluctuations is cost-push shocks whose contributions to fluctuations in output, consumption and investment turns out to be around 17 percent, 15 percent, and 26 percent respectively.

Put together, the numbers above show that shocks to productivity, consumer preferences, and the price mark-up together account for up to 87 percent of output fluctuations which suggests that GDP is mainly influenced by demand and supply shocks rather than the policy shocks. Nevertheless, one should not play down the importance of policy, especially monetary policy, in influencing the real economy. This is because monetary policy is shown to be an important driver of investment for which it contributes up to 22 percent of its variability. In other words, the Keynesian monetary policy transmission mechanism appears to be functional.

Lastly, although the role of monetary policy in directly influencing total output is quite mild, its role in the movement of prices is much more pronounced. More than 45 percent of the overall inflation dynamics are explained by changes in monetary policy thus making it the most important variable in our model, influencing prices. This level of influence is much higher than that established by VAR models of Ngalawa (2010) and Mangani (2012) both of whom found the exchange rate (a variable not featured in our closed economy model) to be the biggest influencer of prices. Therefore extending our model to include the external sector is an interesting idea for future research.

5. Conclusions

In summary, this paper has examined Malawi's fiscal and monetary policies in a closed economy New-Keynesian DSGE model with multiple shocks. The model that is developed has been estimated by the Bayesian estimation method using flexible priors and quarterly data on seven macroeconomic variables that include consumption, investment, government spending, consumer prices, nominal interest rate, consumption tax revenue, and income tax revenue.

The main contributions of the study are threefold. Firstly, policy feedback rules for both monetary and fiscal policy have been estimated and with that, how fiscal and monetary authorities in Malawi react to macroeconomic instability has been established. Secondly, new evidence on the effects of the fiscal and monetary policy in Malawi on key macroeconomic variables including consumption and investment has been established. And thirdly, the comparative importance of the different fiscal policies, monetary policy, and other demand and supply shocks, in the determination of business cycles and price movements has also been established.

The study finds that both monetary and fiscal policies react to output fluctuations rather mildly. However monetary policy is found to react strongly to inflation and it does so by raising interest rates in accordance with the Taylor principle. The study also establishes that whilst all the policy feedback rules affect business cycles in the conventional ways, it is actually shocks to productivity, consumer preferences, and price mark-ups that contribute the most to output fluctuations, with productivity shocks being by far the most dominant.

Given these results, one obvious message to macroeconomic policy makers in Malawi is to recognize that productivity shocks dominate the economy and therefore affect the extent to which fiscal and monetary policy can achieve their objectives. With this in mind, our recommendation is for the government to increase its efforts on improving and maintaining a high the level of productivity in the economy. This can be achieved by promoting the adoption of new productivity enhancing technologies, and by investing in technology improving research and development. One specific case that is applicable here the issue of severe electric power outages that the country has been facing constantly. Given the importance of reliable electricity supply to production process, these power outages serve as negative productivity shocks. In order to address these problems, the Malawi government has embarked on some projects designed to increase power generation. However, for one reason or another, these projects have largely stalled.[12]

[12] see Malawi-Mozambique power interconnection project, and the Khammwamba Thermal Power Station

Therefore, completing and getting these projects fully operational would be in line with our recommendation for enhancing the effectiveness of fiscal and monetary policies.

Another recommendation given the results of our study is for the monetary authorities to maintain their strong monetary policy stance with regards to inflation since this is shown to be an effective way towards maintaining price stability. However caution has to be exercised with regards to how such a strong monetary policy stance affects investment. Overreliance on monetary policy in pursuing price stability could hinder the growth of the economy in the long run by limiting private investment. Instead, price stability would optimally be achieved by addressing structural issues facing the economy such as the low levels of productivity and the constant disruptions of the same that we mentioned above.

Similarly, fiscal authorities need to be cautious of the crowding out effect that government spending has on private investment and consumption. Like with monetary policy, this has the potential of significantly hindering economic growth in the long run. In this regard, we recommend strong coordination between the fiscal authorities and monetary authorities when deciding how to finance government spending shocks as this can help ensure that the cost of credit and the amount available for the private sector is not significantly affected by expansions in government spending. Thus this would help minimize the crowding out of private investment and consumption.

As is with most studies based on simplified macroeconomic models, this one too faces several limitations that the reader needs to be aware of. One limitation comes from the fact that the sample size that is used for estimation purposes is quite small. This is necessitated by the availability of data. Nevertheless, this issue is partly addressed by the fact that the study employs the Bayesian estimation method and therefore supplements potential deficiencies in the data with prior information about the parameters in the model.

Secondly, as has already been mentioned before, another limitation of the study is that the model upon which our analysis is based is a closed economy model. But as Ngalawa (2011) and Mangani (2012) show in their VAR models, exchange rate movements appear to be very important in influencing inflation dynamics in Malawi. Therefore the fact that our model does not allow us to explore the role that the exchange rate plays is a notable limitation.

Lastly, the reader should take caution regarding the potential sources of the lack of persistence in the inflation and investment effects of monetary policy. We recognize that while this is a typical feature of these kinds of models, it could be a sign of excluded nominal rigidities. Therefore, adding features to the model such as sticky wages and sticky information could be explored to see whether they improve the performance of the model with regards to the impact of monetary policy shocks.

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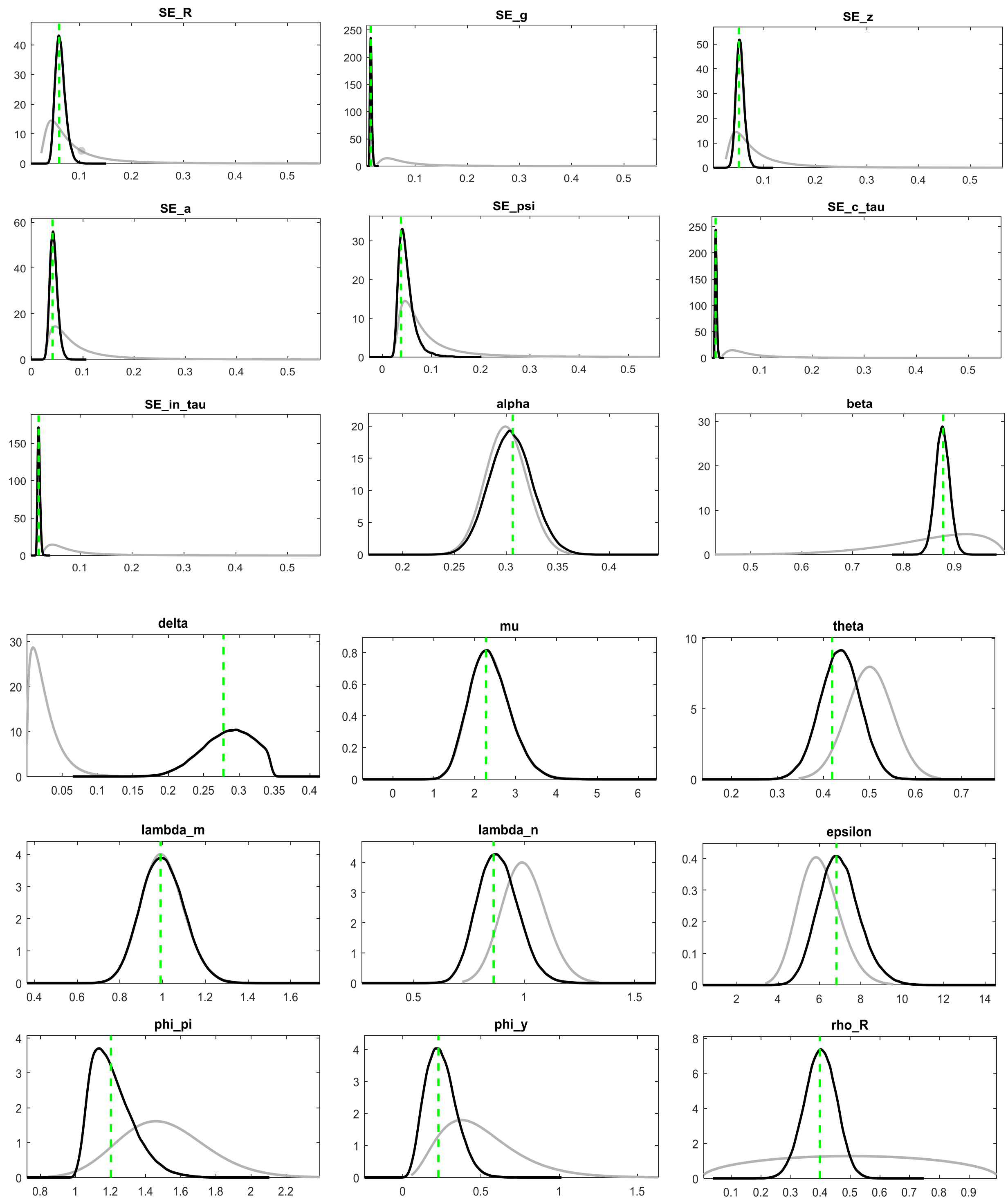
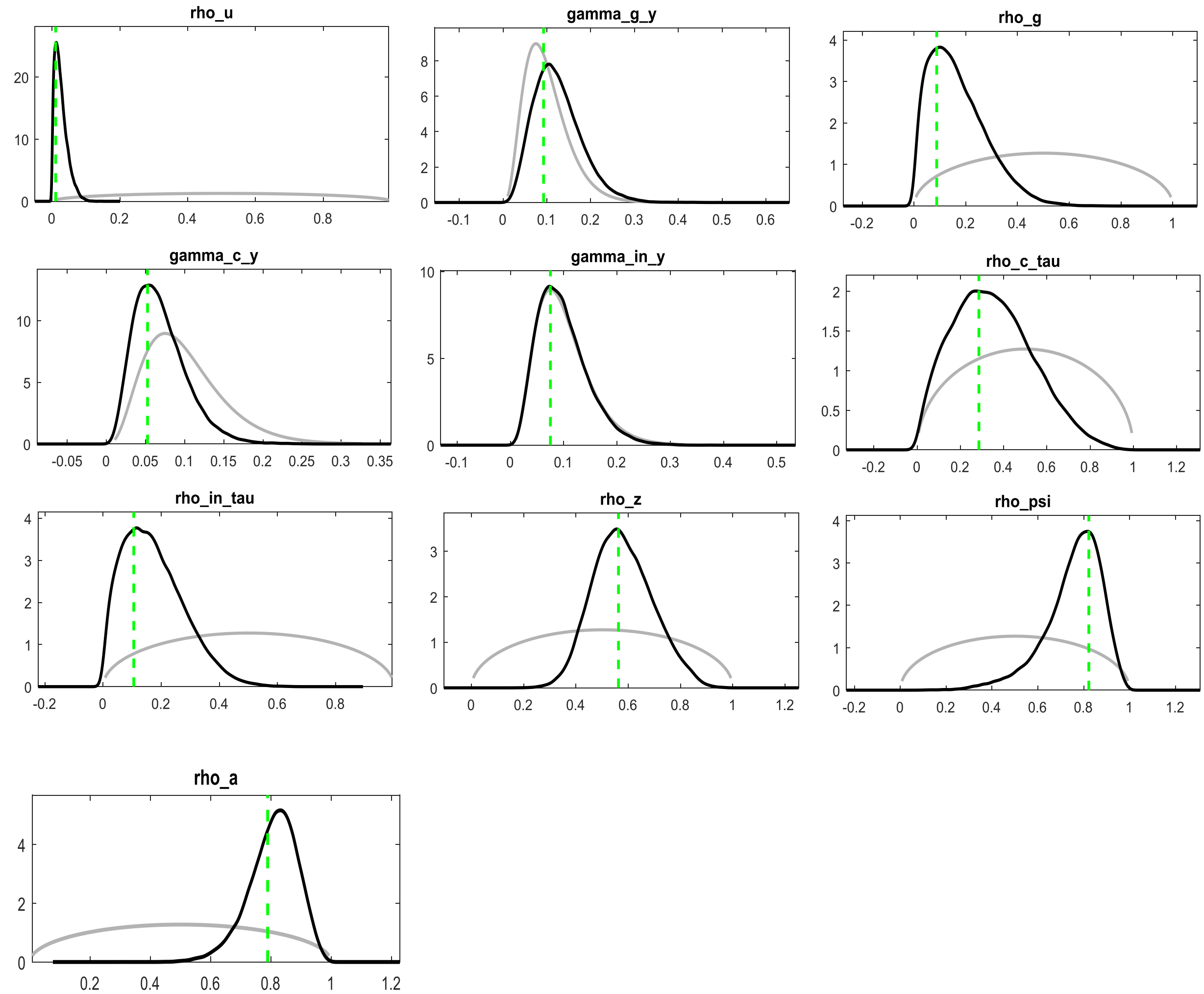
Appendices

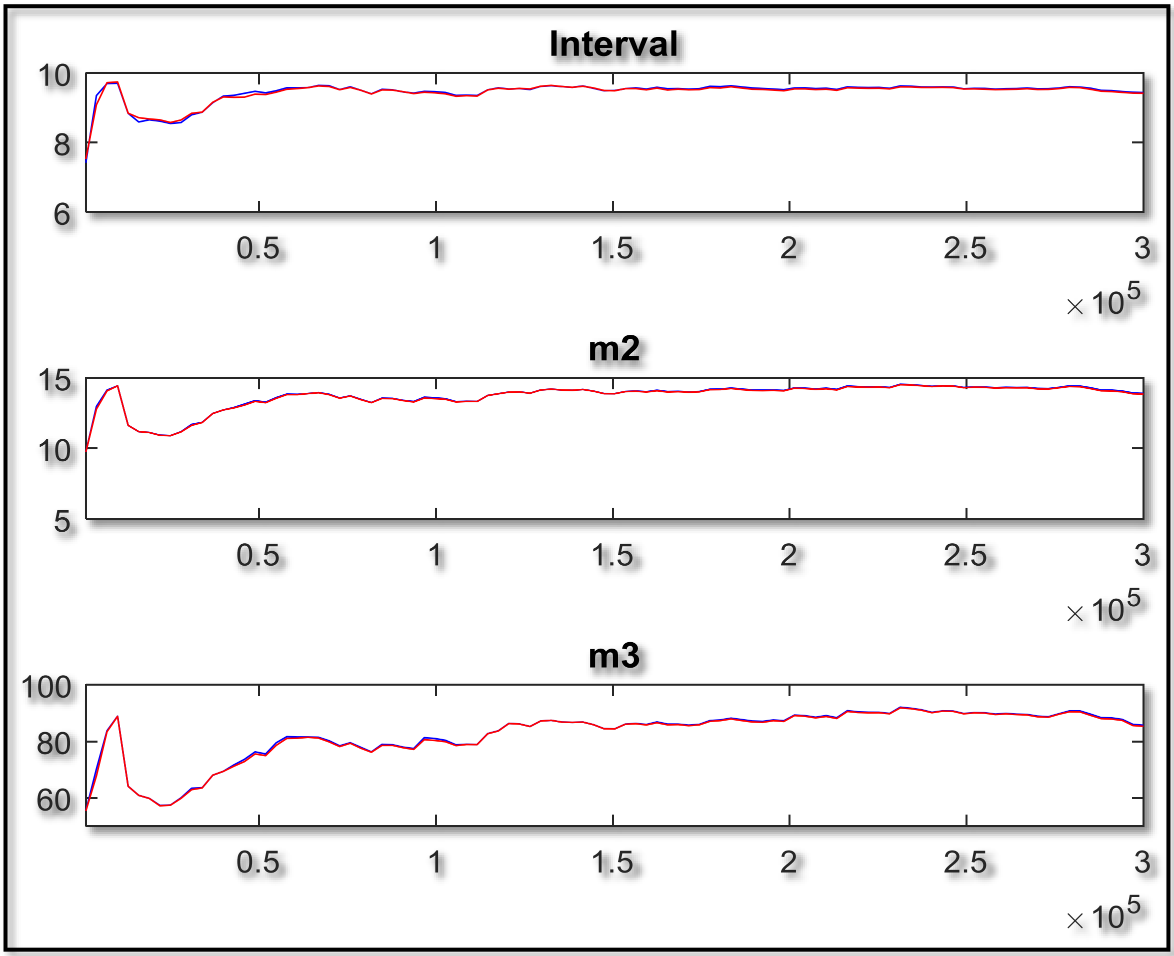
Appendix 1: Prior and posterior distributions




rho_u
gamma_g_y
rho_g
gamma_c_y
gamma_in_y
rho_c_tau
rho_in_tau
rho_z
rho_psi
rho_a

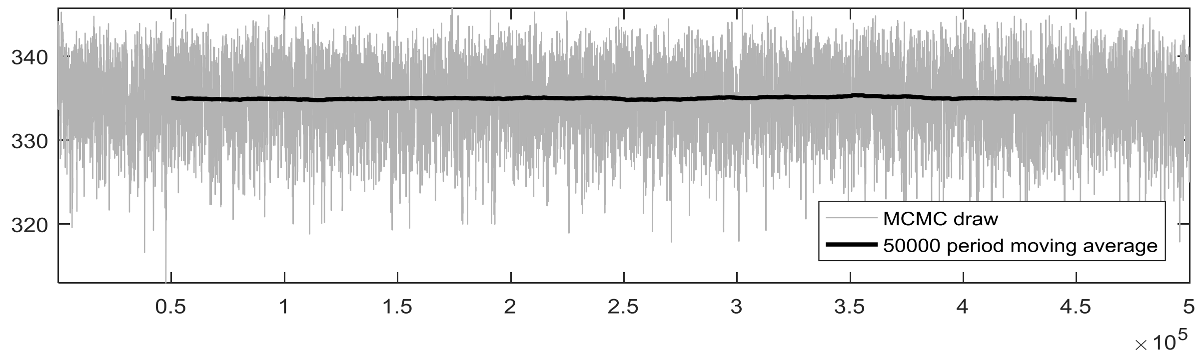
Appendix 2: Convergence diagnostics

Appendix 2.1: Multivariate convergence diagnostics

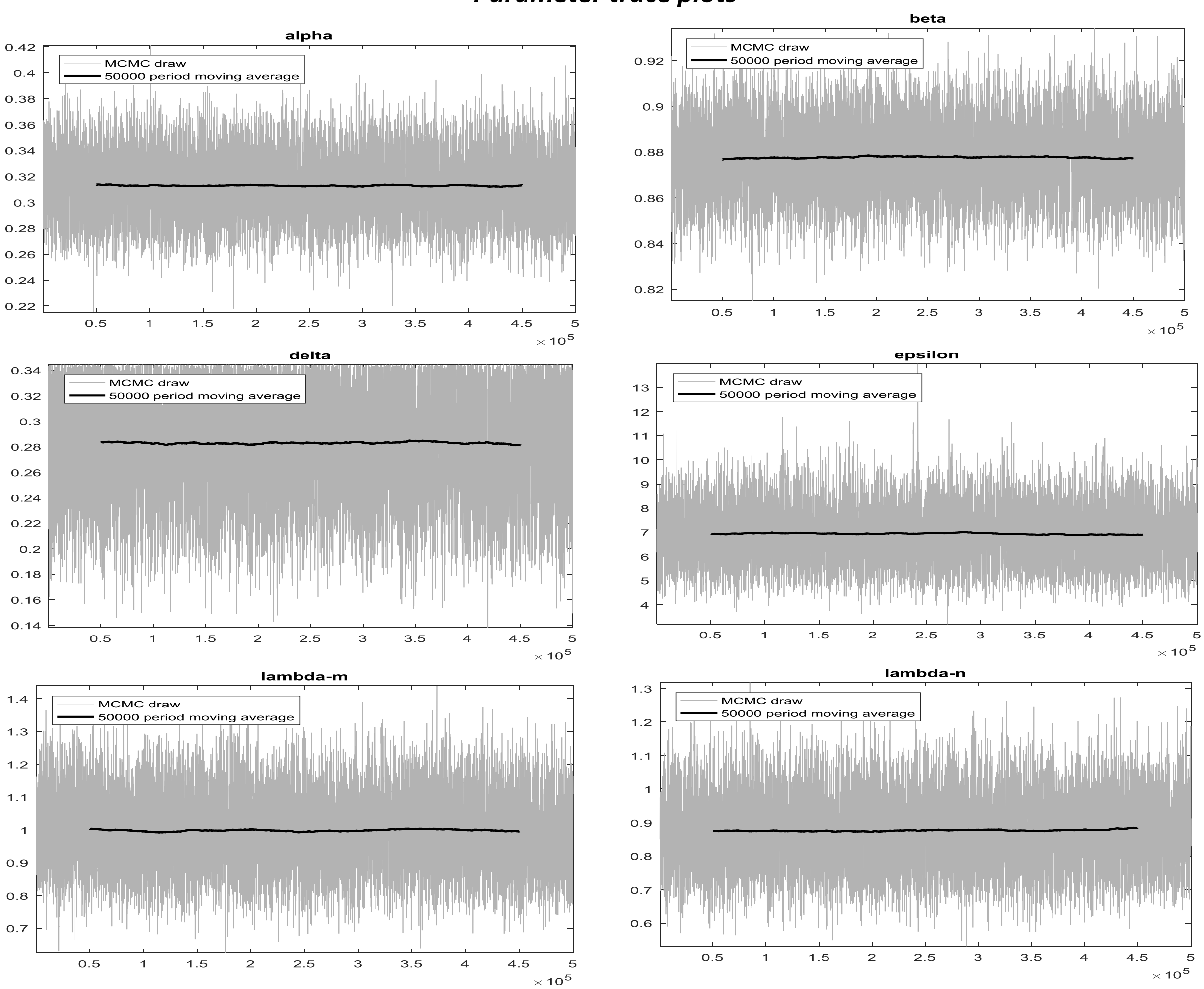


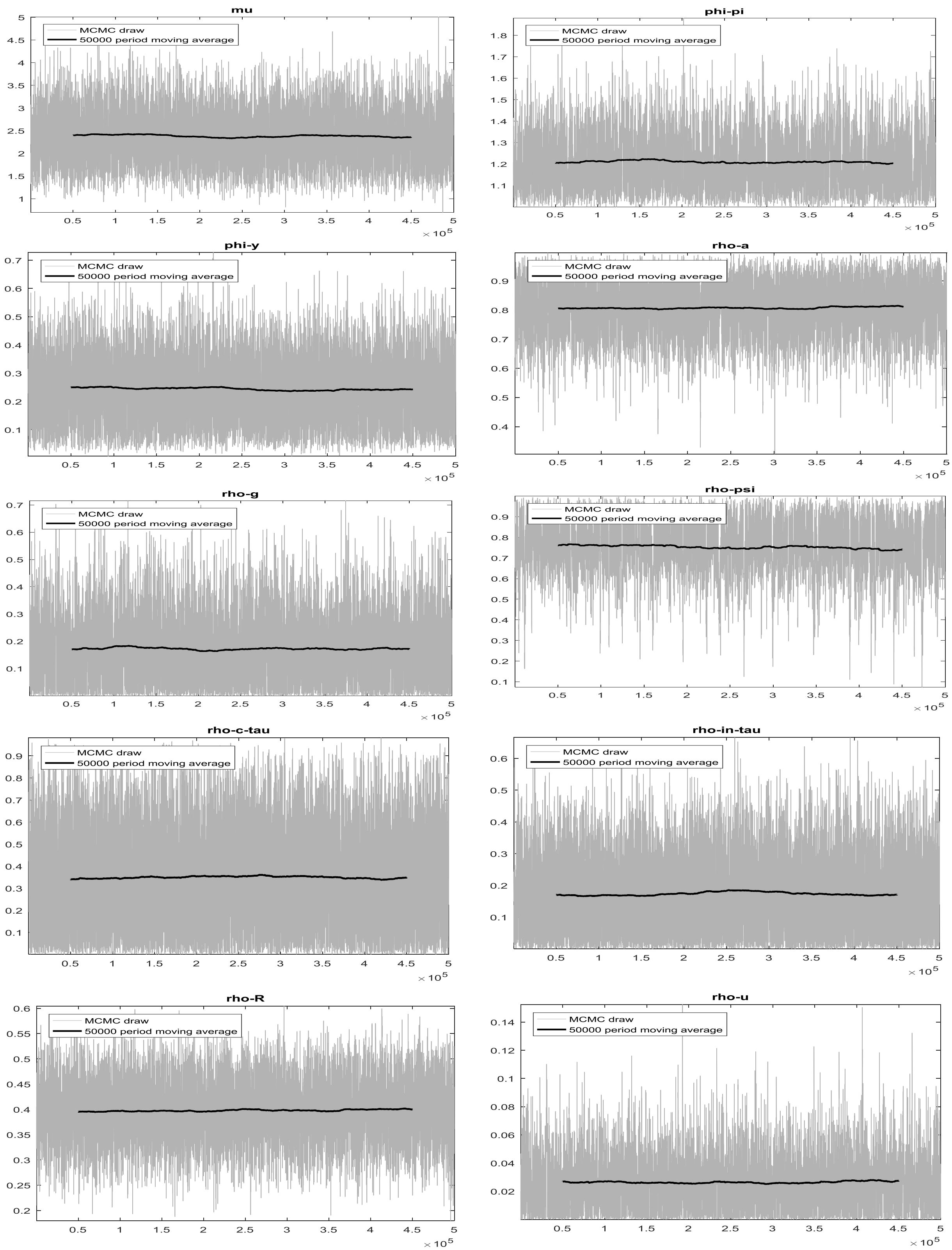
Appendix 2.2: Trace plots

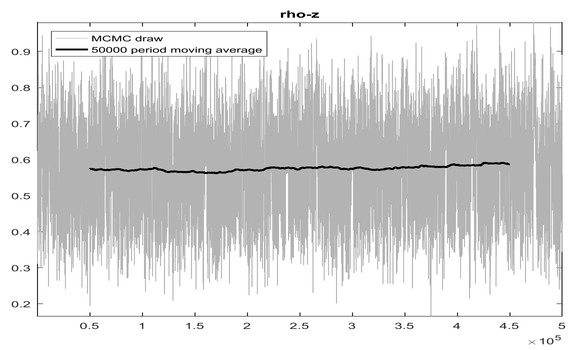
Trace plot for the posterior density

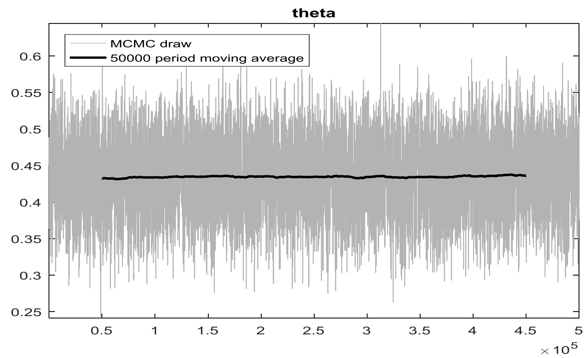


Parameter trace plots




mu
MCMC draw
50000 period moving average
phi-pi
MCMC draw
50000 period moving average
phi-y
MCMC draw
50000 period moving average
rho-a
MCMC draw
50000 period moving average
rho-g
MCMC draw
50000 period moving average
rho-psi
MCMC draw
50000 period moving average
rho-c-tau
MCMC draw
50000 period moving average
rho-in-tau
MCMC draw
50000 period moving average
rho-R
MCMC draw
50000 period moving average
rho-u
MCMC draw
50000 period moving average


rho-z
MCMC draw
50000 period moving average
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
× 10^5


theta
MCMC draw
50000 period moving average
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
× 10^5