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Monetary policy and financial frictions in a small open-economy model for Uganda

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Abstract
This paper considers the role of financial frictions and the conduct of monetary policy in Uganda. It makes use of a dynamic stochastic general equilibrium model, which incorporates small open-economy features and financial frictions that are introduced though the activities of heterogeneous agents in the household. Most of the parameters in the model are estimated with the aid of Bayesian techniques and quarterly macroeconomic data from 2000q1 to 2015q4. The results suggest that the central bank currently responds to changes in the interest rate spread, despite the fact that capital and financial markets are relatively inefficient in this low-income country. In addition, the analysis also suggests that to reduce macroeconomic volatility, the central bank should continue to respond to these financial sector frictions and that it may be possible to derive a more favourable sacrifice ratio by making use of a slightly more aggressive response to macroeconomic developments.

Keywords Monetary policy · Inflation targeting · Financial frictions · Small open economy · Low-income country · Dynamic stochastic general equilibrium model · Bayesian estimation

JEL Classification E32 · E52 · F41

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1 Introduction

The financial sector plays an important role in a modern economy as it is able to channel savings and provide credit extensions to productive sectors of an economy. It also promotes efficiency by facilitating transactional payments and the management of risk (Svensson 2012). Therefore, disruptions to the financial sector could give rise to macroeconomic instability as it may be responsible for the transmission of shocks to other sectors of an economy.[1] This has important implications for the conduct of monetary policy, as it has also been suggested that instability in the financial sector may be partially attributed to monetary policy actions (Mishkin 1996; Taylor 2009).[2]

Prior to the onset of the Global Financial Crisis, most macroeconomic models made use of frictionless financial markets, as has been characterised in Modigliani and Miller (1958), where businesses could directly source funds from other firms.[3] This feature of the model precludes the use of credit market imperfections where some borrowers, who qualify for credit, may be rationed out of the market at the prevailing interest rate (Stiglitz and Weiss 1981). In addition, this framework would not allow for interactions between monetary policy and financial stability, where excessively low interest rates promote unproductive asset purchases, while high interest rates could give rise to an increase in non-performing loans that would curtail further credit extensions.

While the inclusion of financial sector frictions in monetary policy models has taken centre stage in the policy arena of most developed and some of the advanced emerging market economies, these discussions are yet to find a place in monetary policy research of most low-income countries (LICs). In this regard, the case of Uganda is of particular interest, as it is one of the few LICs that currently employ an inflation-targeting framework where monetary policy may be described by a nominal interest rate rule that is similar to that of Taylor (1993). In addition, the Bank of Uganda (BOU) also has an explicit objective to maintain financial sector stability and as such it would facilitate the natural inclusion of financial sector frictions in a model for monetary policy.[4]

Furthermore, as the structure of the financial and capital markets in Uganda are relatively underdeveloped (as is the case in most LICs), an investigation into the effects of financial frictions within such a setting may provide interesting new findings, where

[1] Gray et al. (2011) describe how various economic factors (including changes to interest rates) affect financial sector credit risks. They also describe how the financial sector affects measures of economic activity. This has been particularly evident during the recent crises, as the Global Financial Crisis [2007], Latin American Crisis [1980], and Asian Crisis [1997] were all mainly triggered by financial sector weaknesses.

[2] Important early contributions that consider the relationship between financial instability and the conduct of monetary policy include Patinkin (1956) and Tobin (1969).

[3] Initial attempts to introduce financial sector frictions into DSGE models by Kiyotaki and Moore (1997) and Bernanke et al. (1999) were never adopted in central banks and other policy institutions prior to the onset of the recent crisis (Quadrini 2011).

[4] This additional objective is been pursued in tandem with the primary role of fostering price stability. At present, financial sector stability models at the BOU are detached from the monetary policy models. This is in many ways similar to many other countries, which partly reflects the institutional arrangements in central banks, where macroeconomic models that are used for forecasting and policy analysis reside in monetary/economic policy analysis divisions, while financial system analysis models reside in the bank supervision/financial stability divisions (Vlcek and Roger 2012).

weakness in the financial sector may reduce the effectiveness of monetary policy, while contributing towards the proportion of non-performing loans.[5] For example, the banking sector in Uganda is dominated by a few commercial banks where there is limited creditor information due to the missing or underdeveloped credit reference bureau agencies, problems with providing physical addresses and weaknesses in the national identification systems. In addition, most of the other financial markets, such as those for fixed-income securities and equities are not particularly effective.[6]

The Ugandan macroeconomic data, which spans the period 2000q1 to 2015q4, also incorporates a number of large policy shocks that are of particular interest to those who are concerned with the effects of financial frictions, where the central bank increased its policy rate by 1000 basis points during a period of heightened inflationary pressures in 2011. Shortly, after this period, non-performing loans (measured as a share of gross loans) more than doubled, from 1.81 to 4.65% within the period of a year, and the annual growth rate for private sector credit declined to 3.9 from 46.4%.

Therefore, this paper seeks to extend the literature that considers the role of financial frictions in macroeconomic models by applying such frictions to a model for the Ugandan economy. This extension is motivated by the recent work by Baldini et al. (2015), who suggest that structural macroeconomic models have the ability to improve the quality of quantitative macroeconomic policy analysis in LICs. The dynamic stochastic general equilibrium (DSGE) model in this paper makes use of the financial frictions framework of Curdia and Woodford (2010), which are incorporated within the context of small open-economy model that is described in Justiniano and Preston (2010). To the best of our knowledge, this is the first attempt that has been made to estimate a dynamic macroeconomic model that incorporates financial frictions for an inflation-targeting LIC.

The results of this analysis suggest that the financial sector is an important facet of the Ugandan economy, despite the fact that it is relatively underdeveloped. In addition, the estimation of parameters in the model shows that the central bank currently responds to financial sector frictions in accordance with its broad mandate. As a part of an optimal policy investigation, we also note that it is indeed optimal for the central bank to respond to these financial sector developments and that by increasing its response to changes in output, inflation and the interest rate spread, it may foster lower aggregate levels of macroeconomic volatility and a slightly more favourable sacrifice ratio.[7]

The rest of the paper is organised as follows. Section 2 describes the features of the model, while Sect. 3 describes the data. Thereafter, Sect. 4 provides details of the

[5] In the November 2012 monetary policy statement by the Governor of the BOU, it was noted that "…whereas inter-bank rates, wholesale deposit interest rates and securities yields have all followed the downward trend of the central bank rate, commercial bank lending rates have been sticky downwards" (Tumusiime-Mutebile 2012).

[6] Such features would suggest that the bank lending channel for monetary policy transmission may be dominated by the effects of changes in the central bank short-term interest rates, which influence that rate that is charged by commercial banks on loans and paid on deposits (Mishra et al. 2010).

[7] Where the definition of the sacrifice ratio is the amount of output growth that is sacrificed to reduce the level of inflation (Ball 1994).

estimation methodology and the prior parameter distributions, while the results are contained in Sect. 5. The final section contains the conclusion.[8]

2 The model

The structure for a small open-economy model follows the work of Gali and Monacelli (2005) and Justiniano and Preston (2010), where the foreign economy is represented by the weighted average of the key variables of its trading partners. Financial sector frictions are then introduced with the aid of heterogeneous household agents, as has been applied in Curdia and Woodford (2010).

2.1 Heterogeneous households

Following Curdia and Woodford (2010), the representative households are grouped into savers, denoted by s, and borrowers, denoted by b. This categorisation is assumed to be influenced by the differences in the levels of marginal utility of consumption, where the borrowing households have a higher rate of marginal utility for current period consumption. This feature allows for a role for financial intermediation, where savers either deposit excess income with financial intermediaries, or they invest in risk-free bonds. These instruments pay the prevailing gross policy rate, R_t for domestic bonds, or R_t^* in case of foreign bonds. The borrowing households may then consume in excess of their income during the current period after they obtain credit from financial intermediaries at an interest rate that is equivalent to the gross lending rate, R_t^b. The presence of these heterogeneous households that have different objectives establishes a relationship between the gross policy rate and the lending rate, where $R_t^b > R_t$.

To change from being borrowers to savers (and vice versa), we utilise a two-state Markov chain process, with a transition probability, $1 - \Omega$. In terms of the initial state probabilities, the proportion of saving households is represented by the probability π_s, and the borrowing households are represented by the probability π_b. Therefore, each household type seeks to maximise the following expected discounted utility:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[u^{\tau_t(i)} \left(C_t(i); \varsigma_t^{gc} \right) - v^{\tau_t(i)} \left(n_t(i); \varsigma_t^{gc} \right) \right], \tag{1}$$

where $\tau_t(i) \in \{s, b\}$ denotes the household's type in period t, β is the discount factor, $C_t(i)$ is the current level of consumption for each household type, and $n_t(i)$ represents the hours of labour supply that are provided by each household type. It is then assumed that the preference shock, ς_t^{gc}, follows a first-order autoregressive process, $\varsigma_t^{gc} = \rho_{gc} \varsigma_{t-1}^{gc} + \eta_t^{gc}$.

[8] An additional online appendix includes a brief review of the literature that considers the application of structural macroeconomic models in LICs. It also incorporates further details relating to the data, the full log-linear specification of this model and additional figures that relate to the estimation results.

The utility from consumption and labour supply take the forms:

$$u^{\tau_t(i)}\left(C_t(i);\,\varsigma_t^{gc}\right)\equiv\varsigma_t^{gc}\frac{\left(C_t(i)-h_\tau C_{t-1}^{\tau}\right)^{1-\sigma_\tau}}{1-\sigma_\tau},$$

and

$$v^{\tau_t(i)}\left(n_t(i);\,\varsigma_t^{gc}\right)\equiv\varsigma_t^{gc}\Lambda_L\frac{n_t(i)^{1+\sigma_L}}{1+\sigma_L},$$

where σ_τ is the inverse elasticity of intertemporal substitution, σ_L is the inverse elasticity of labour supply, and h_τ captures the degree of habit formation in consumption. The Λ_L parameter denotes the steady state of labour supply and the average level of consumption that was chosen by all households in the previous period is C_{t-1}^{τ}.

The average level of household consumption comprises of a composite index consisting of both domestically produced and foreign produced goods,

$$C_t=\left[(1-\alpha)^{\frac{1}{\eta}}C_{H,t}^{\frac{\eta-1}{\eta}}+\alpha^{\frac{1}{\eta}}C_{F,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$$

where $C_{H,t}$ and $C_{F,t}$ denote the consumption of domestically produced and foreign produced goods, and the parameter $\alpha\in[0,1]$ denotes the degree of openness as measured by the fraction of imported goods in households consumption. The parameter, η, denotes the elasticity of substitution between home and imported goods. The consumption of these goods would then evolve according to the constant elasticity of substitution (CES) function,

$$C_{H,t}=\left[\int_0^1 C_{H,j,t}^{\frac{\varepsilon-1}{\varepsilon}}\mathrm{d}j\right]^{\frac{\varepsilon}{\varepsilon-1}}\quad\text{and}\quad C_{F,t}=\left[\int_0^1 C_{F,j,t}^{\frac{\varepsilon-1}{\varepsilon}}\mathrm{d}j\right]^{\frac{\varepsilon}{\varepsilon-1}}$$

where ε represents the elasticity of substitution between the different types of goods.

The net domestic financial wealth of each household at the start of the period takes the form:

$$A_t(i)=\left[B_{t-1}(i)\right]^{+}R_{t-1}+\left[B_{t-1}(i)\right]^{-}R_{t-1}^{b}+D_t^{int}$$

where $B_{t-1}(i)$, represents the net domestic financial wealth of the household in the previous period. In this case, $[B]^{+}\equiv\max(B,0)$ denotes the household with positive income balances, and $[B]^{-}\equiv\min(B,0)$ denotes the household with negative balances. It is assumed that profits from financial intermediaries, D_t^{int}, are shared by savers and borrowers.

The equation that describes the evolution of household net domestic wealth may then be expressed as:

$$D_t+B_t^{g}=\int_{\mathcal{S}_t}A_t(i)\,\mathrm{d}i\quad\text{and}\quad L_t=-\int_{\mathcal{B}_t}A_t(i)\,\mathrm{d}i,$$

where B_t^{g} denotes risk-free government bonds at the end of each period, D_t represents the aggregate household deposits with the financial intermediaries, and L_t denotes the aggregate household borrowing from financial intermediaries. In this case, $\mathcal{B}_t$ denotes the set of households for whom, $A_t(i) < 0$ and $\mathcal{S}_t$ denotes the set of households for whom $A_t\,(i) \geq 0$.

In order to obtain the budget constraint for the households, we assume that the nominal interest rate on foreign bonds is subject to a risk premium, which increases with the stock of foreign bonds in domestic currency (c.f. Schmitt-Grohé and Uribe 2003; Justiniano and Preston 2010). Hence, the remuneration on foreign bonds may be expressed as $R_t^*\phi_{t-1}$, where ϕ_t is the risk-premium factor. The household stock of foreign asset holdings can then be expressed in terms of domestic currency, $e_t B^*$, where e_t is the nominal exchange rate. Given these assumptions, the household's total bond holdings are given by, $B_t + e_t B^* \leq R_{t-1}B_{t-1} + R_{t-1}^*\phi_{t-1}e_t B_{t-1}^*$, and the household's budget constraint would take the form:

$$P_t C_t + B_t + e_t B^* = R_{t-1}B_{t-1} + R_{t-1}^*\phi_{t-1}e_t B_{t-1}^*(a_t) + W_t n_t + T_t \qquad (2)$$

where a_t represents the net asset position of the domestic economy, W_t denotes the nominal wage rate, and T_t denotes the lump-sum taxes and transfers. The term P_t represents the domestic consumer price index. The country risk premium and the net-foreign-asset position of the domestic economy may then be expressed in terms of domestic currency and the steady-state level of output,

$$\phi_t = \exp\left(\tilde{\phi}_t - \psi a_t\right) \text{ and } a_t = \frac{e_{t-1}B_{t-1}^*}{\bar{Y}P_{t-1}},$$

where ψ is the parameter that describes the relationship between the foreign bond holdings and the output trend in the domestic economy. The steady-state level of real output is then given as $\bar{Y}$, and $\tilde{\phi}_t$ is the exogenous risk-premium shock which evolves according to the autoregressive process, $\tilde{\phi}_t = \rho_\phi\tilde{\phi}_{t-1} + \eta_t^\phi$.

The households optimisation problem would then reduce to a decision that relates to the level of expenditure that should be allocated towards domestically produced and foreign produced goods. The optimal expenditure allocation for each good that is within the continuum $j \in [0, 1]$ is determined by the demand for each of the goods and can be expressed as:

$$C_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\theta} C_{H,t} \text{ and } C_{F,t}\,(j) = \left(\frac{P_{F,t}(j)}{P_{F,t}}\right)^{-\theta} C_{F,t},$$

where $P_{H,t}$ and $P_{F,t}$ denote the price indices for domestically produced and imported goods, respectively. The two prices could then be expressed with the aid of the Dixit–Stiglitz aggregate functions:

$$P_{H,t} = \left(\int_0^1 P_{H,j,t}^{1-\theta}\mathrm{d}j\right)^{\frac{1}{1-\theta}} \text{ and } P_{F,t} = \left(\int_0^1 P_{F,j,t}^{1-\theta}\mathrm{d}j\right)^{\frac{1}{1-\theta}}.$$

Under the assumption of asymmetry between all goods, the domestic expenditure on domestic and foreign goods is given as

$$C_{H,t}=(1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta}C_t \text{ and } C_{F,t}=\alpha\left(\frac{P_{F,t}}{P_t}\right)^{-\eta}C_t,$$

where the aggregate consumer price index is expressed as, $P_t = \left[(1-\alpha)P_{H,t}^{1-\eta} + \alpha P_{F,t}^{1-\eta}\right]^{\frac{1}{1-\eta}}$. Total consumption expenditure by the domestic households is then, $P_t C_t = P_{H,t}C_{H,t} + P_{F,t}C_{F,t}$.

Given the utility function in (1) and the budget constraint in (2), it is relatively straightforward to derive the first-order conditions with respect to the choice variables, $C_{i,t}$, L_t, $(D_t + B_t)$ and B_t^*.

2.2 Firms

Production in the economy involves a continuum of monopolistically competitive firms that supply intermediate goods. Perfectly, competitive final goods producers use these inputs to supply finished products to the household and government sectors.

2.2.1 Intermediate goods producers

The differentiated intermediate goods are indexed by j and are produced by firms that make use of the following linear production function:

$$Y_{j,t} = Z_t n_{j,t}$$

where Z_t captures the exogenous productivity shock that evolves as an AR(1) process and $n_{j,t}$ represents the amount of labour inputs used in the production of intermediate goods.

Nominal rigidities are introduced into the intermediate goods producing sector with the aid of the Calvo (1983) pricing mechanism, where a subset of firms adjust their prices to a new level with probability $(1-\theta_H)$. This implies that the size of θ_H would determine the degree of price stickiness in the domestic economy. Additional persistence is introduced through an indexation rule, where current domestic prices are determined by the price level and the inflation rate from the previous period,

$$\log P_{H,t} = \log P_{H,t-1} + \delta_H \pi_{H,t-1}$$

where the inflation rate is $\pi_{H,t} = \log(P_{H,t}/P_{H,t-1})$ and δ_H is a measure of the degree of indexation relative to the previous periods inflation rate. Therefore, the evolution of the price index for home goods would be:

$$P_{H,t} = \left[\theta_H\left(P_{H,t-1}\pi_{H,t-1}^{\delta_H}\right)^{1-\varepsilon} + (1-\theta_H)P_H^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}.$$

The problem faced by each intermediate goods producing firm that has the ability to change price is to maximise the expected present discounted value of earnings. Hence, the intermediate firm seeks to solve the following optimisation problem,

$$\max \mathbb{E}_t \sum_{T=t}^{\infty} \theta_H^{T-t} Q_{t,t+k} Y_{j,t+k} \left[P_{H,t} \pi_{H,t+k-1}^{\delta} - P_{H,t+k} MC_{t+k} \right]$$

subject to the condition that production of intermediate goods equals the demand for intermediate goods by the final goods producers:

$$Y_{j,t} = \left[\frac{P_{H,t}(j) \pi_{H,t+k-1}^{\delta_H}}{P_{H,t}} \right]^{-\varepsilon} Y_t$$

where $MC_{t+k} = W_{t+k}/(P_{H,t+k} Z_{t+k})$ represents the real marginal cost of each firm that produces intermediate goods and θ_H^{T-1} denotes the probability that these firms will not adjust prices in the next $(T-t)$ periods. Hence, the firms optimisation problem gives rise to the following first-order condition:

$$\mathbb{E}_t \sum_{T=t}^{\infty} \theta_H^{T-1} Q_{t,t+k} Y_{j,t+k} \left[P_{H,t} \pi_{H,t+k-1}^{\delta} - \frac{\theta_H}{\theta_H - 1} P_{H,t+k} MC_{t+k} \right] = 0.$$

2.2.2 Final goods producers

The transformation of intermediate goods into final goods is described by the constant elasticity of substitution (CES) production function,

$$Y_t = \left[\int_0^1 Y_{j,t}^{\frac{1}{\lambda_t}} \mathrm{d}j \right]^{\lambda_t} \tag{3}$$

where $\lambda_t = \theta_t / (\theta_t - 1)$ represents the time-varying markup and θ_t represents the elasticity of substitution between the intermediate goods. After solving the first-order condition for the profit maximisation problem of the final goods producing firm, the demand function for each intermediate good j can be expressed as:

$$Y_{j,t} = \left(\frac{P_t}{P_{j,t}} \right)^{\frac{\lambda_t}{\lambda_t - 1}} Y_t.$$

Similarly, after making use of (3) and rearranging, we obtain a relationship that expresses the final goods aggregate price level in terms of intermediate goods prices:

$$P_t = \left[\int_0^1 P_{j,t}^{\frac{1}{1-\lambda_t}} dj \right]^{1-\lambda_t}.$$

where λ_t follows an AR(1) process. Then, lastly the foreign demand for domestic goods, $C_{H,t}^*$, could be expressed as,

$$C_{H,t}^* = \left(C_{H,t-1}^* \right)^{\delta} \left[\alpha^* Y_t^* \left(\frac{P_t}{e_t P_t^*} \right)^{-\eta} \right]^{1-\delta}$$

where δ measures the relationship between previous exports and current exports and α^* is the share of foreign produced goods in the overall expenditure of the foreign economy.

2.2.3 Foreign produced goods

Firms in the foreign market operate in a monopolistically competitive market, where they employ the Calvo price setting framework with the addition of indexation of current period prices to past inflation. The fraction of firms that are able to change prices is given by $(1-\theta_F)$ and the firms set prices according to an indexation rule that is similar to the one employed by domestic intermediate goods producers. Hence, the aggregate price index for the foreign produced goods is,

$$P_{F,t} = \left[\theta_F \left(P_{F,t-1}\pi_{F,t-1}^{\delta_F}\right)^{1-\varepsilon} + (1-\theta_F)\, P_F^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}.$$

2.3 The real exchange rate and the terms of trade

As in the case of a small open-economy model, it is assumed that the law of one price (LOP) holds for the export sector, while there is incomplete pass-through for the import sector as the domestic retailers may apply different margins on imports.

2.3.1 The terms of trade

The bilateral terms of trade (TOT), $S_{j,t}$, between the home country and a foreign country is the measure of the relative price of the home country's imported goods in terms of home produced goods, $S_{j,t} = P_{j,t}/P_{H,t}$. When this ratio is computed for the home country and all the trading partner countries, the resultant ratio is referred to as the effective TOT, S_t, and may be expressed as:

$$\begin{aligned} S_t &\equiv \frac{P_{F,t}}{P_{H,t}} \\ &= \left(\int_0^1 S_{i,t}^{1-\gamma}\, \mathrm{d}i\right)^{\frac{1}{1-\gamma}}. \end{aligned} \tag{4}$$

2.3.2 Law of one price

The difference between import prices in the domestic and foreign economy that is due to the monopolistic competition among retailers is captured by the law of one price gap, $\psi_{F,t}$, which is expressed as,

$$\psi_{F,t} = \frac{e_t P_{F,t}^*}{P_{F,t}}$$

where e_t is the nominal exchange rate, and $P^*_{F,t}$ is the price of the imported goods in the foreign economy. Since the domestic country's exports constitute a small fraction of the total world trade, $P^*_{F,t}$ can be approximated by the foreign consumer price index, P^*_t. Therefore, the TOT in (4) may then be written as:

$$S_t = \frac{e_t P^*_t}{P_{H,t}}.$$

2.3.3 Real exchange rate

Foreign inflation and domestic exchange rate depreciation affect the TOT by making exported goods more expensive. Hence, the real exchange rate, Q_t, could be described as,

$$Q_t = \frac{e_t P^*_t}{P_t}.$$

2.4 International risk sharing and uncovered interest parity

To close-off the open-economy features of the model, we adopt the assumption of complete asset markets with international risk sharing to induce stationarity, as per Gali and Monacelli (2005). A detailed discussion on the approaches to close-off small open-economy models is contained in Schmitt-Grohé and Uribe (2003). Using the intratemporal optimality condition for the external economy, we are able to derive the conditions,

$$Q^i_{t+1} = \beta \left(\frac{C^i_{t+1}}{C^i_t}\right)^{-\sigma} \left(\frac{P^i_t}{P^i_{t+1}}\right)\left(\frac{e^i_t}{e^i_{t+1}}\right) \text{ and } C_t = \vartheta_i C^i_t Q^{\frac{1}{\sigma}}_{i,t}.$$

Due to the assumption of complete international financial markets and free capital movement, the expected nominal return from risk-free bonds in the domestic economy would equal the expected nominal return of a similar bond in the foreign economy, when expressed in domestic currency. As a result, the stochastic discount factor in the domestic and foreign economy would be equal, and may be expressed as:

$$\beta\left[\frac{\lambda_{t+1}}{\lambda_t}\frac{P_t}{P_{t+1}}\right] = Q_{t,t+1} = \beta\left[\frac{\lambda^*_{t+1}}{\lambda^*_t}\frac{P^*_t e_t}{P^*_{t+1} e_{t+1}}\right].$$

This expression may be used to obtain the uncovered interest rate parity (UIP) condition in the log-linearised form,

$$\mathbb{E}_t q_{t+1} - q_t = (r_t - \mathbb{E}_t \pi_{t+1}) - \left(r^*_t - \mathbb{E}_t \pi^*_{t+1}\right) + \phi_{uip} a_t + \varepsilon^{rp}_t$$

where $q_t = e_t + p^*_t - p_t$ represents the expression for the log-linear real exchange rate. The term $\phi_{uip} a_t$ denotes the country risk premium, where the coefficient ϕ_{uip} is the elasticity parameter in the UIP condition and a_t is the net-foreign-asset position of the country. It is then assumed that the risk-premium shock, ε_t^{rp}, follows an AR(1) process. This condition allows for the common expression for the net-foreign-asset position in the domestic country, which takes the form:

$$a_t = \frac{1}{\beta} a_{t-1} - \alpha \left(s_t + \psi_{F,t} \right) + y_t - c_t.$$

2.5 Financial intermediaries

The financial intermediaries take real deposits, d_t, and lend a fraction of these deposits in the form of real loans, l_t. We assume that a fraction, $\chi_t(l_t)$, of the loans that were extended will not be repaid at the end of the period. The loss rate depends on macroeconomic conditions (such as, economic activity, the inflation rate and interest rates). The operations of the financial intermediaries are restricted to the domestic economy and their real profits, which are discounted by the expected fraction of loan defaults, may be given as:

$$D_t^{int,r} = d_t - l_t - \chi_t(l_t)$$

where $\chi_t(l_t) = \chi_t^{1+\eta_\chi}$. In addition, we assume that the loans that are extended in period t are paid in the following period, $t+1$. At the time of repayment, the intermediaries receive, $l_t R_t^b$, which allows the intermediaries to pay $d_t R_t$ to the savers for their deposits. Therefore, the earnings of the financial intermediaries would depend on the spread (ω_t) between the lending rate (R_t^b) and the deposit rate (R_t), which is expressed as:

$$R_t^b = \omega_t R_t.$$

Thus, the financial intermediaries problem reduces to the maximisation of profits that is influenced by the level of loans, l_t, where the first-order condition for the interest rate spread is derived as,

$$\omega_t = 1 + \left(1 + \eta_\chi\right) \chi_t l_t^{\eta_\chi} + \eta_\Phi \Phi_t l_t^{\eta_\Phi - 1}.$$

This implies that the interest rate spread is an increasing function of the fraction of non-performing loans, χ_t, and the volume of loans extended, l_t (when $\eta_\Phi > 0$). Hence, when economic activity is in decline, the balance sheets of firms could be negatively affected, which constrains the ability of the firms to pay back the borrowed funds. This could lead to an increase in non-performing loans. In addition, an increase in inflation could erode the households wealth and weaken their ability to pay back borrowed funds, or alternatively, it could reduce the real value of borrowed funds, which would make it easier for firms to pay back loans. Therefore, we express the evolution of non-performing loans as:

$$\chi_t = \chi_{t-1}^{\rho_\chi} \Theta_t^{-\theta_\chi} \epsilon_t^\chi$$

where $\Theta_t > 0$ is a measure of the economic conditions indicator (output and/or inflation), and ϵ_t^{χ} denotes an exogenous shock to the fraction of non-performing loans.

2.6 Government

Government expenditure evolves relatively smoothly over time and may be described by the process,

$$g_t = \left(1 - \rho_g\right) g + \rho_g g_{t-1} + \eta_t^{g_t}.$$

where, g is the steady-state level of government spending and $\eta_t^{g_t}$ represents the shock to government spending. After the variable is demeaned and we assume that the steady-state level of government spending is zero, this expression reduces to,

$$g_t = \rho_g g_{t-1} + \eta_t^{g_t}$$

2.7 Central bank

The BOU adopted an inflation-targeting framework in 2011. Thus, it is assumed that the central bank's monetary policy framework follows the generalised Taylor (1993) rule, where the short-term nominal interest rate is adjusted in response to developments in core inflation, the output gap (measured as the deviation of actual output from its stochastic trend), and nominal exchange rate depreciation.[9] Ugandan monetary policy also responds to financial conditions (but mostly in an *ad hoc* manner), where during periods of rapid credit growth, monetary policy could be tightened to induce a slowdown in credit growth. Similarly, a relatively expansive monetary policy could be pursued when private sector credit growth decelerates. Vredin (2015) and Woodford (2012) suggest that by including measures of financial stability into the monetary policy rule, the central bank may induce welfare enhancing conditions. Therefore, the monetary policy rule takes the form,

$$R_t = \rho_R R_{t-1} + (1 - \rho_R)\left[\phi_\pi \pi_t + \phi_y y_t + \phi_{\triangle e} \triangle e_t - \phi_\omega \omega_t\right] + \varepsilon_t^R$$

where ρ_R is the parameter that measures the degree of interest rate smoothing, ϕ_π is the weight attached to inflation, ϕ_y represents the central bank response to changes in output, and ϕ_e is the weight attached to nominal exchange rate depreciation. The parameter for the central bank response to the financial friction is ϕ_ω, which is associated with the measure of the interest rate spread. In this case, the negative sign for the coefficient suggests that the nominal interest rate should be lowered when the lending spread increases (c.f. Taylor 2009; McCulley and Toloui 2008). The term ε_t^R is an uncorrelated monetary policy shock that follows an AR(1) specification.

[9] The inclusion of exchange rate in the Taylor rule is supported by Blanchard et al. (2010), who suggest that central banks in small open-economies should openly recognise exchange rate stability as part of their objective function.

2.8 Foreign economy

The foreign economy is assumed to be exogenous to the domestic economy, where the key relationships are modelled as AR(1) processes,

$$
\begin{aligned}
y_t^* &= \rho_{y^*} y_{t-1}^* + \eta_t^{y^*} \\
\pi_t^* &= \rho_{\pi^*} \pi_{t-1}^* + \eta_t^{\pi^*} \\
R_t^* &= \rho_{R^*} R_{t-1}^* + \eta_t^{R*}
\end{aligned}
$$

where y_t^*, π_t^* and R_t^* denote foreign economy measures for output, inflation and the interest rate, respectively.

2.9 Aggregate demand and output

Lastly, it is assumed that the goods market clears in the domestic economy, which requires that the domestic output matches the sum of domestic consumption and foreign consumption of all domestically produced goods. Hence,

$$
y_t = (1 - \alpha) C_{H,t} + \alpha C_{H,t}^*
$$

Using the demand functions that have already been defined, we can then derive the relationships:

$$
C_{H,t} = (1 - \alpha) \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} C_t \text{ and } C_{H,t}^* = \alpha \left(\frac{e_t P_{H,t}}{P_t^*} \right)^{-\eta} C_t^*.
$$

3 Data

The model makes use of quarterly data for Uganda and its main trading partners. The sample spans the period 2000q1 to 2015q4, which includes all available quarterly output data for the Ugandan economy. Over this period, the main objective of the central bank has always been price stability; however, the official policy of the central bank was one of the monetary aggregate targeting (which was implemented as a form of pseudo inflation-targeting) prior to July 2011. Thereafter, formal inflation targeting was adopted. When considering the properties of the data, we note that the evolution of the key interest rates during the two possible regimes (prior and post 2011) are fairly similar, which would suggest that monetary policy has been consistently applied over the full sample from 2000q1.

The analysis makes use of ten observed variables to estimate the model parameters. These include measures of the nominal interest rate, consumer price inflation, output, terms of trade, real exchange rate, lending rate, non-performing loans, foreign output, foreign inflation rate and foreign interest rate. The measures for the foreign economy are computed from the trade weights of Uganda's key trading partners (as used in the calculation of the real effective exchange rate). The variables that have seasonal patterns are seasonally adjusted and all the variables are demeaned to provide implied steady-state values of zero. The domestic data are sourced from the BOU and the Uganda Bureau of Statistics (UBOS), while the foreign economy data are sourced from the Organisation for Economic Co-operation and Development (OECD) and the International Monetary Fund (IMF).[10]

4 Estimation methodology

The model is estimated with the aid of Bayesian methods.[11,12] In the case of this model, the Kalman filtering technique is used to construct the likelihood function for the DSGE model as many of the variables are unobserved.

While the objective was to estimate most of the parameters, it was necessary to calibrate a few of the parameters that could not be identified by the ten observed variables. The values for the calibrated parameters are derived from similar studies or the long-run properties of the data. In this regard, the discount factor, β is set to 0.9951, following Berg et al. (2010a), who look to match the trend in the Ugandan real interest rate. The constant in the disutility of labour, Λ_L is set to 7.5, which implies that households work for 8 h a day, on average. To calibrate the coefficient that represents the degree of openness in the domestic economy, α, the average historical ratio of imports to gross domestic product over the last ten years is used and is set to 29%. This implies that roughly one-third of the output in the domestic economy is imported.

Due to the scarcity of data for the labour market, the labour supply elasticity, σ_L, is set to 2.5. This is a typical value that is found in the literature and was also used in Berg et al. (2010a). The elasticity of substitution between home and imported goods, η, is then set to 1.5, which falls within the 1–2 range found in the general literature. For the parameters that are used to introduce financial frictions into the small open-economy model, the calibration is largely based on Curdia and Woodford (2010). The parameter reflecting the initial share of borrowers in the economy, π_b is set to 0.5, which implies that we assume that there is an equal number of savers and borrowers for the initial iteration. Furthermore, it is assumed that it takes approximately 10 years on average, before a household can change from borrower to saver (and vice versa), as the transition probability, Ω, is set to 0.975. Borrowers are assumed to be more willing to substitute consumption than savers and hence the relative ratio between the two types, σ_b/σ_s, is set to 2. It should be noted that Curdia and Woodford (2010) used values of both 2 and 5 for this ratio, but as we assume that the household types may

[10] Further details relating to the data and the transformations that have been applied are included in the online appendix.

[11] An and Schorfheide (2007) and Fernández-Villaverde (2010) provide an informative summary of the advantages that may be derived from estimating these models with Bayesian techniques.

[12] The estimation procedure utilises a Markov Chain Monte Carlo (MCMC) algorithm and the Brooks and Gelman (1998) measure of convergence, where five chains of 100,000 draws are used for randomly selected starting values. The average acceptance rate for all the chains is about 25.07%, and for each chain, 40,000 draws are kept after the initial burn in phase. Convergence is monitored with the aid of univariate and the multivariate diagnostic MCMC plots and suggests that it is achieved after about 50,000 draws.

not react all that strongly to changes in interest rates in Uganda, we make use of the more conservative value in this case.[13]

Lastly, for the financial intermediation process, the parameter reflecting the steady-state lending spread, ω, is calibrated to $1.110^{1/4}$, which corresponds to an annual spread of about 1100 basis points. In addition, the steady state of the non-performing loans, χ, is calibrated to 5%, which matches the historical average of the ratio of non-performing loans to total loans observed in the Ugandan data. The parameter measuring the persistence in this variable, ρ_χ, is set at 0.8, a value obtained from a simple regression. The measure of non-performing loans elasticity, η_χ, is set to 1, as we assume a uniform relationship between lending, non-performing loans and the lending spread.

4.1 Prior distributions

Table 1 presents a summary of the first two moments of the priors and their distributions. Beta distributions are used for the parameters that are restricted to lie between zero and one, while gamma distributions are used for the parameters that take on positive values. The structural shocks are assumed to follow independent inverse-gamma distributions.

Most of the values for the first two moments of the prior parameter distributions follow Berg et al. (2010a), Berg et al. (2010b) and Justiniano and Preston (2010). Therefore, the parameter for the habit formation of savers follows a beta distribution with a mean of 0.7 and a relatively small standard deviation of 0.05. The Calvo price parameters allow for the presence of nominal rigidities, which is measured by the level of price stickiness in the domestic (θ_H) and foreign (θ_F) economy. It is assumed that these parameters take on beta distributions with reasonably flat prior values, where the mean values are 0.5 and the standard deviations are set at 0.1. Similarly, the indexation parameters for the domestic and foreign economy (δ_H and δ_F) are also assigned beta distributions with identical mean and standard deviation values (as per the Calvo parameters). An inverse-gamma distribution is utilised for the ratio that measures the elasticity of non-performing loans to output, where the prior mean value is 0.4 and the standard deviation is 0.1. The external risk premium, ϕ, is assumed to follow an inverse-gamma distribution with a mean value of 0.01, following Justiniano and Preston (2010).

For the monetary policy rule, the prior parameter for persistence in interest rate shocks follows a beta distribution and its mean and standard deviation are set to 0.8 and 0.05, respectively. The other prior parameters, which measure the central bank reaction to developments in output, inflation and the exchange rate, are all assumed to follow gamma distributions with mean values set to 1.7, 0.5 and 0.05, respectively. The corresponding standard deviations are 0.1, 0.05 and 0.03. Lastly, the parameter that introduces the evolution of financial conditions in the policy reaction function follows a gamma distribution with a prior mean of 0.4 and a standard deviation is 0.1.

[13] The existence of relatively underdeveloped financial and capital markets and statements by the central bank Governor on the inefficiency of monetary policy transmission would support a more conservative estimate for these parameters.

Table 1 Prior and Posterior estimation results

Description	Parameter	Density[a]	Prior		Posterior	
			Mean	SD	Mean	10–90% int.
Consumption						
Habit formation (savers)	b_s	B	0.7	0.05	0.661	[0.554; 0.772]
Calvo parameters						
Domestic prices	θ_H	B	0.5	0.1	0.835	[0.811; 0.865]
Imported prices	θ_F	B	0.5	0.1	0.19	[0.148; 0.234]
Indexation						
Domestic prices	δ_H	B	0.5	0.1	0.266	[0.149; 0.374]
Import prices	δ_F	B	0.5	0.1	0.346	[0.199; 0.496]
Exchange rate						
Risk premium	ϕ_{uip}	IG	0.01	Inf	0.004	[0.002; 0.005]
Non-performing loans						
NPL/output elasticity	θ_y	G	0.4	0.1	0.395	[0.233; 0.546]
Taylor rule						
Smoothing	ρ_R	B	0.8	0.05	0.81	[0.769; 0.851]
Inflation	ϕ_π	G	1.7	0.1	1.819	[1.642; 1.997]
Output gap	ϕ_y	G	0.5	0.05	0.536	[0.449; 0.624]
Exchange rate	$\phi_{\triangle e}$	G	0.05	0.03	0.043	[0.006; 0.08]
Interest rate spread	ϕ_ω	G	0.4	0.1	0.407	[0.241; 0.576]
Persistence parameters						
Technology	ρ_z	B	0.8	0.1	0.409	[0.272; 0.553]
Government spending	ρ_g	B	0.8	0.1	0.8	[0.646; 0.961]
Preference	ρ_{gc}	B	0.8	0.1	0.756	[0.632; 0.923]
Cost push	ρ_{cp}	B	0.8	0.1	0.942	[0.897; 0.99]
Risk premium	ρ_{rp}	B	0.8	0.1	0.681	[0.532; 0.82]
Foreign inflation	$\rho_{\pi *}$	B	0.8	0.1	0.565	[0.418; 0.712]
Foreign output	ρ_{y*}	B	0.8	0.1	0.858	[0.785; 0.938]
Foreign interest rate	ρ_{R*}	B	0.8	0.1	0.872	[0.801; 0.892]
Structural shocks						
Technology	η^z	IG	0.054	Inf	0.113	[0.075; 0.155]
Government spending	η^g	IG	1.3	Inf	1.327	[0.294; 2.221]
Preference	η^c	IG	0.05	Inf	0.281	[0.074; 0.463]
Cost push	η^{cp}	IG	0.2	Inf	0.21	[0.148; 0.27]
Risk premium	η^{rp}	IG	0.04	Inf	0.028	[0.018; 0.038]
Non-performing loans	η^χ	IG	1.5	Inf	1.231	[1.049; 1.406]
Monetary policy	η^R	IG	0.6	Inf	0.007	[0.006; 0.008]
Foreign inflation	η^{π^*}	IG	0.01	Inf	0.007	[0.006; 0.008]
Foreign output	η^{y^*}	IG	0.04	Inf	0.006	[0.005; 0.006]
Foreign interest rate	η^{R^*}	IG	0.04	Inf	0.001	[0.001; 0.001]

[a] *B* beta, *G* gamma, *IG* inverse-gamma

The value for the mean value of this prior parameter is similar to the posterior estimate that was derived in Steinbach et al. (2014).

All the other persistence parameters are assumed to be fairly large and this is reflected by their beta prior mean values that are set at 0.8, with standard deviations of 0.1. As is the practice in most studies, the parameters for the structural shocks take small mean values and an infinite standard deviation.

5 Results

5.1 Parameter estimates

The posterior parameter mean estimates and their corresponding 10–90% percentiles are presented in Table 1.[14] In general, the results suggest that the posterior parameter estimates fall within a plausible range, when compared to the literature. Notably, the parameter that captures the response of the monetary authority to changes in the lending spread (ϕ_ω) has a mean posterior estimate of -0.407. This estimate is close to the one obtained in Steinbach et al. (2014) for the South African economy, but falls below the one-for-one adjustment that was proposed in McCulley and Toloui (2008) and Taylor (2009).

The parameter that measures the degree of habit formation of savers has an estimated value of 0.66, which falls within the values found in the literature. The estimates for the nominal price rigidities suggest that the prices for domestic goods are revised after every 6 quarters (on average), while the prices for foreign goods are revised every 1.4 quarter (on average). This implies that there is a relatively high degree of persistence of domestic goods prices. The relatively low persistence of foreign goods prices could reflect the effects of frequent exchange rate movements.

The inflation indexation parameter for both domestic goods prices and foreign goods prices are estimated to be around 0.3 and 0.4, respectively. This implies that the price indexation process for both type of goods place a high weight on current inflation, relative to past inflation. The estimate for the risk-premium parameter in the UIP condition is fairly small at 0.003, while the parameter estimate that measures the responsiveness of non-performing loans to changes in output is 0.39.

The estimates for the parameters in the monetary policy rule suggest that the degree of interest rate smoothing by the central bank is 0.81. This would suggest that the BOU places a relatively large weight on interest rate stabilisation when conducting monetary policy.[15] In addition, the parameter that captures the response of the central bank to changes in inflation has a posterior parameter estimate of 1.82, which is slightly higher than what was envisaged but still within range that is reported in the literature. This would suggest that the BOU reacts relatively aggressively to inflationary pressures. The parameters that measure the reaction of the central bank to changes in output and the exchange rate are estimated to be 0.54 and 0.04, respectively.

[14] The prior and posterior density plots have been included in the online appendix.

[15] A number of researchers have also suggested that large estimates for the interest rate smoothing parameter indicate relatively persistent inflationary shocks (Rudebusch 2002).

When considering the persistence in the shocks, we note that the cost-push shocks are the most persistent, which would suggest that the shocks to the measure of core inflation subside over a relatively long period of time. The estimates for the standard deviation of these shocks suggest that the foreign interest rate displays the least amount of volatility, while government spending shocks are more volatile than expected.

5.2 Impulse response functions that follow a financial shock

A financial shock is represented by a positive innovation to non-performing loans due to an increase in the lending spread. Such a shock influences the endogenous variables in the model, as displayed in Fig. 1. To show the effects of including the financial friction in the monetary policy rule, we generate an additional set of estimation results, where we set $\phi_\omega = 0$, for comparative purpose. In this case, the impulse response functions without financial frictions are represented by the solid line, while the results of the model with financial frictions are represented by the dashed line.[16] In addition, we also consider the result of making use of relatively large values of ϕ_ω, such as those that are presented in Curdia and Woodford (2010), where the dotted and dot-dash lines represent $\phi_\omega = 0.75$ and $\phi_\omega = 1$.

Note that in the model with financial frictions, a positive innovation to the lending spread induces a similar change to the lending rate faced by borrowers. Consequently, the level of borrowing in the economy declines as new loans become expensive. The slow down in borrowing constrains economic activity, which reduces demand pressure and inflation. These factors allow for the monetary authority to lower the central bank interest rate, which results in a nominal exchange rate depreciation as foreign exchange inflows fall. The terms of trade follows a similar path as the nominal exchange rate, due to the combined effect of domestic inflation and exchange rate developments.

When we consider the response of the variables, in the model that does not include financial frictions, we note similar behaviour. However, in this case, the monetary policy actions are more muted as the lending spreads are not included in the response function. Despite this behaviour, the level of borrowing declines by a greater margin in the model that excludes financial frictions as this element helps to reduce the effect of the increased spread on the level of borrowing. This suggests that there would be a relatively higher level of credit in the economy when the monetary policy model incorporates financial frictions. When comparing the impulse response functions of the two models, it is also worth noting that inflation overshoots by a slightly higher magnitude in the model with financial frictions. However, it converges to the pre-shock level in roughly the same amount of time.

Then finally, when comparing the results that are attributed to the estimated value of ϕ_ω, with the impulse response functions for larger values for this parameter, we note that the change in the respective variables move in a similar direction following a

[16] Since we are looking to compare the impulse response functions from two models in this case, the results reflect the mean dynamic responses of the variables. The corresponding Bayesian impulse response functions that include 90% confidence intervals for the posterior distributions are included in the online appendix.

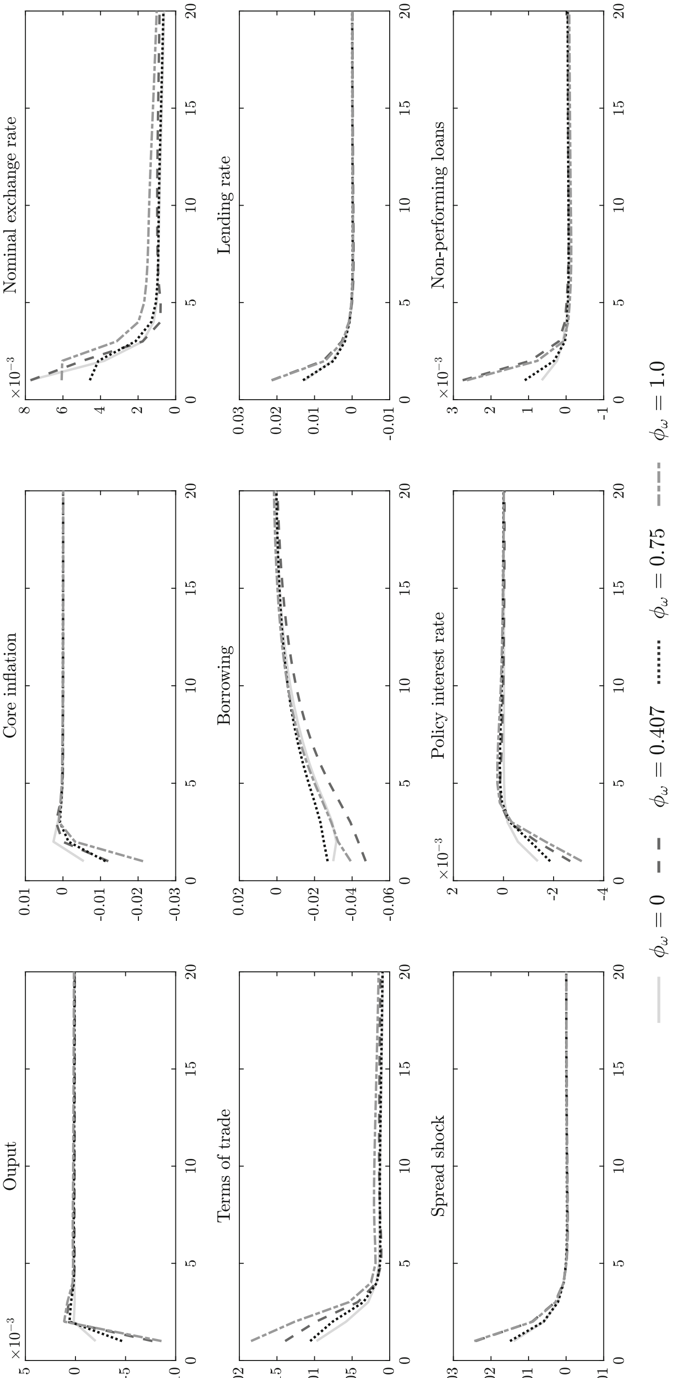

Fig. 1 Impulse response of a financial shock

financial shock. In this case the magnitude of the movement in each variable is slightly different.

5.3 Impulse response functions that follow a monetary policy shock

Figure 2 displays the response of selected variables in the model to a monetary policy shock, which is represented by an increase in the central bank interest rate. Such a shock gives rise to a similar change in the lending rate, which results in a decrease in the level of borrowing and a decline in economic activity. This makes it difficult for firms to service their loans, and the level of non-performing loans would subsequently increase. The fall in economic activity also contributes to a decline in inflation, while the exchange rate appreciates as the increase in the domestic interest rate attracts foreign exchange inflows.

The effect of the monetary policy shock largely dissipates after about 6 to 7 quarters. However, its effect on the financial variables (which include the borrowing level and non-performing loans) takes longer to erode and after 20 quarters these variables are yet to attain their pre-shock levels.

5.4 Historical decompositions

Figure 3 displays the historical decomposition for the measures of output and inflation. The figures suggest that the model variables are mainly driven by shocks to consumption preferences, non-performing loans, consumer prices, technology, government spending and the risk premium. While the influence of monetary policy shocks is relatively small. This is partly due to the fact that monetary policy mainly responds to other shocks, such as cost-push shocks.[17]

These results suggest that the major driving forces that give rise to a change in output include non-performing loans, foreign output shocks, the risk-premium and cost-push shocks. It is worth noting that during 2009, following the onset of the global financial crisis, there are three particularly large shocks to non-performing loans that are largely responsible for a decline in output growth over this period. In addition, during the period 2011–2012, when Uganda experienced excessive inflationary pressure, innovations due to cost-push shocks had a pronounced negative effect on output. When comparing the relative influence of the shocks in the pre- and post-crisis period, we note that the cost-push shocks and the risk premium have become slightly more influential at the expense of non-performing loans.

The historical decomposition of the core inflation rate suggests that inflationary pressure in Uganda is mostly driven by cost-push shocks, while innovations to non-performing loans, foreign output, government spending and the risk premium are also important. Once again, following the onset of the global crisis, we note that an increase in non-performing loans eased inflationary pressure. Thereafter, we also note that the onset of the inflationary spike in 2011 was largely attributed to excessive cost-push shocks, while non-performing loans and risk-premium shocks also contributed to an

[17] The results from the historical decompositions of the real exchange rate, terms of trade, policy rate and lending rate are contained in the online appendix.

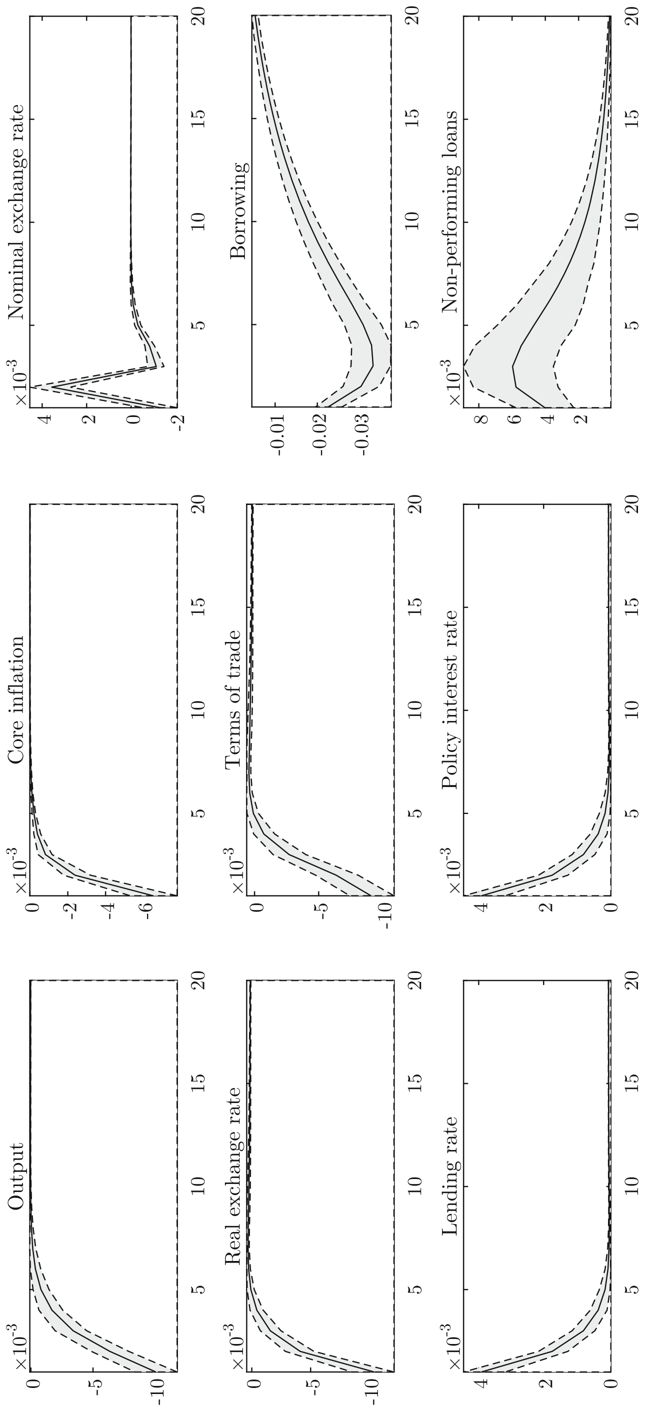

Fig. 2 Impulse response of a monetary policy shock

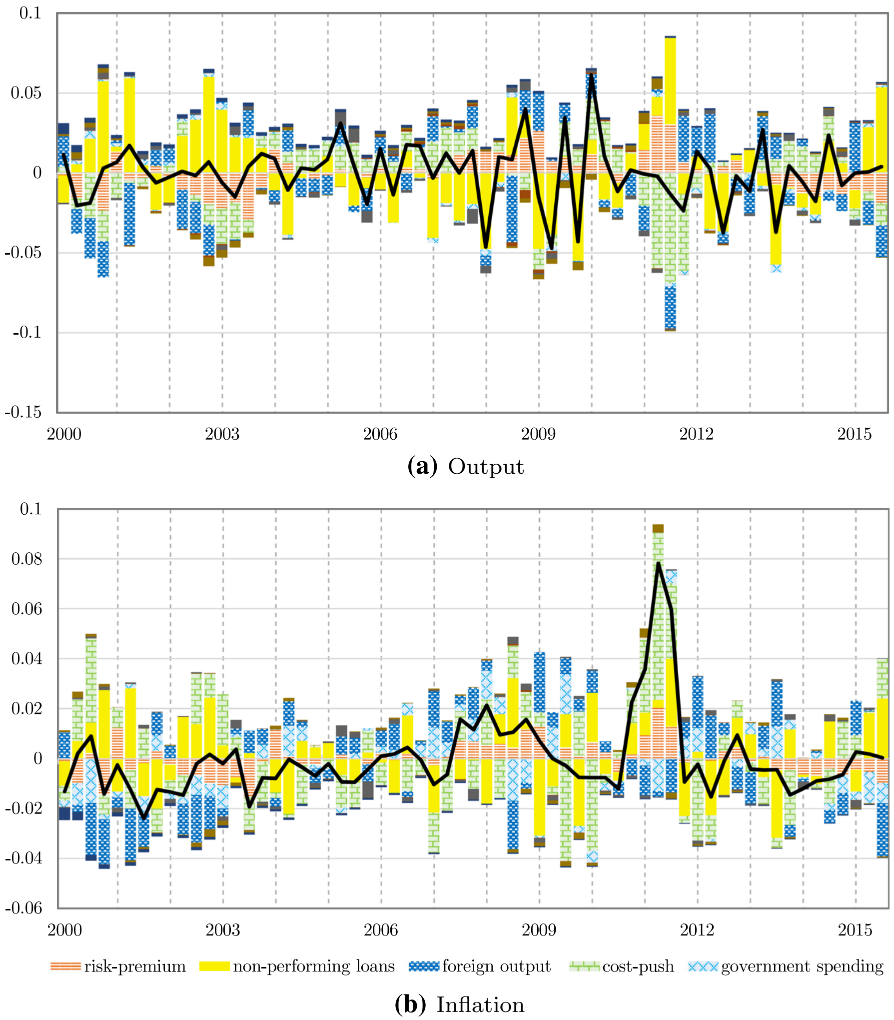

Fig. 3 Historical decompositions

increase in this rate of inflation. Towards the end of this period when the central bank raised the benchmark policy rate, non-performing loans rose, and this shock together with the decline in the cost-push shock helped to relieve inflationary pressure.[18]

The additional results, which are contained in the online appendix, suggest that shocks from non-performing loans, government spending and consumer prices are the main driving forces behind the lending rates in Uganda. For instance, the increase in lending rate between 2011 and 2012 was largely driven by a monetary policy tightening that sought to reduce inflationary pressure (that was due to several large cost-push

[18] When comparing the influence of the shocks on inflation during the pre- and post-crisis subsamples, we note that cost-push have become more prominent, although this is possibly due to the inflationary spike in 2011, rather than the onset of global financial crisis.

shocks). Similarly, during this period, shocks from non-performing loans also pushed lending rates upwards, as commercial banks implemented stricter credit policies.

5.5 Optimal monetary policy rule for reduced volatility

This section considers the use of an optimal monetary policy rule that would reduce the volatility in key macroeconomic variables. To satisfy this objective, we identify the parameter estimates in the monetary policy rule that minimise a loss function that incorporates the second-order moments of selected macroeconomic variables. Our specification of the central bank loss function takes into account the inflation-targeting monetary policy regime that the BOU follows. Hence, we assume that in addition to the desire to achieve inflationary targets, the central bank also pursues other objectives such as the stabilisation of output, exchange rate and interest rates. Furthermore, since the model includes financial frictions, the volatility in the interest rate spread is also included in the loss function of the monetary authority.[19] The loss function may then be expressed as:

$$\begin{aligned} &L_t(\phi_\pi, \phi_y, \phi_{\triangle e}, \phi_\omega, \rho_r) \\ &\quad = \min \mathbb{E} \sum_{t}^{\infty} \beta^t \left[(\pi_t)^2 + \lambda_y (y_t)^2 + \lambda_{\triangle e} (\triangle e_t)^2 + \lambda_\omega (\omega_t)^2 + \lambda_R (R_t)^2 \right] \end{aligned}$$

where $\lambda_\iota \geq 0$ and $\iota = \{y, \triangle e, \omega, R\}$ refer to the parameters that capture the relative weights that the monetary authority places on the variations in output, the exchange rate, the interest rate spread and interest rate smoothing, relative to the variation in inflation. The results from this exercise are presented in Table 2 for two different weighting schemes of λ_ι and for different subsamples, which would allow us to consider any potential change that may have arisen following the onset of the Global Financial Crisis. In addition, the estimated monetary policy rule coefficients have also been included in this table for comparative purposes.[20]

When we consider the results for the full sample, we note that the main difference between the third and fourth columns relates to the assumed relative weight that the monetary authority places on the stabilisation of output and the interest rate. In the third column, it is assumed that the weight the monetary authority places on output stabilisation is half that of the weight that is placed on the smoothing of interest rates. In the fourth column, this assumption is reversed (i.e. the weight that the monetary authority places on the smoothing of interest rates is half that of the weight that is placed on stabilising output). In addition, it is assumed that in both columns (three and four), the monetary authority places relatively small weights on the stabilisation of the exchange rate and the interest rate spread.[21]

19 As noted previously, Woodford (2012) suggests that measures of financial frictions should be included in monetary policy loss functions.

20 The loss function values for the estimated parameters have not been included in this table as it is ultimately derived from the likelihood function, while the loss function for optimal coefficients is derived from the weighted volatility of specific variables. As such, these are not comparable.

21 Additional counter-factual experiments were performed by varying the weights on exchange rate and interest rate spreads between 0.1 to 0.2. These did not change the reported results by a significant degree.

Table 2 Optimal monetary policy rule coefficients

Taylor rule coefficients	Estimated	Optimal rule with weights $(\lambda_y, \lambda_{\triangle e}, \lambda_\omega, \lambda_R)$	
		(0.5, 0.1, 0.2, 1)	(1, 0.1, 0.2, 0.5)
Full sample			
Inflation	1.8194	1.8342	1.8783
Output	0.5361	0.5736	0.6431
Exchange rate	0.0432	0.0344	0.0416
Interest rate spread	0.4069	0.4055	0.4056
Smoothing parameter	0.8101	0.8825	0.6501
Loss function value ($\times 10^{-3}$)		16.1631	15.4417
Subsample 2001q1–2008q3:			
Inflation	1.8663	1.9237	1.9647
Output	0.5175	0.5366	0.5564
Exchange rate	0.0523	0.0284	0.0295
Interest rate spread	0.4014	0.4014	0.4014
Smoothing parameter	0.7166	0.8811	0.8172
Loss function value ($\times 10^{-3}$)		14.1393	12.7556
Subsample 2008q4–2015q4:			
Inflation	1.7348	1.7579	1.7576
Output	0.5116	0.5483	0.5507
Exchange rate	0.0443	0.0415	0.0450
Interest rate spread	0.4044	0.4044	0.4044
Smoothing parameter	0.8718	0.8368	0.7081
Loss function value ($\times 10^{-3}$)		12.5815	13.4544

In general, these results suggest that the estimated parameter values are comparable to the optimal coefficient estimates that are obtained under both assumptions for λ_ι. Specifically, column three suggests that the optimal coefficients for stabilising inflation, output and the interest rate are larger than the estimated monetary policy rule coefficients. Note also that the optimal coefficients for stabilising the exchange rate are relatively small, when compared with the estimated monetary policy rule coefficients. Similarly, column four suggests that the optimal coefficients for inflation and output stabilisation are larger than the estimated coefficients in the monetary policy rule, while the optimal coefficients for the exchange rate and interest rate smoothing are relatively small. In addition, one of the most important findings in this analysis is that the coefficient for the interest rate spread is always larger than 0.4, despite the fact that the weight, λ_ω, is relatively small. This would suggest that to reduce aggregate macroeconomic volatility, the central bank should respond to changes in the interest rate spread when formulating policy and the magnitude of the response is similar to what has been applied.

The aggregate value of the loss function for the full sample would then suggest that the central bank may wish to place relatively more weight on stabilising output and inflation, when the volatility in these variables is relatively important (which is what is reflected in column four, which generates the least amount of aggregate volatility, as measured by the value of the loss function).[22] However, it is also noted that most of the estimated and optimal coefficient values are highly similar and as such it would suggest that the central bank has been conducting near optimal monetary policy over the entire sample.

Similar results are evident for the subsamples that utilise data for before and after the global financial crisis, where the optimal coefficients for inflation and output stabilisation are larger than the estimated coefficients. In addition, we note that both the estimated and optimal coefficients for the interest rate spread is always larger than 0.4 and the optimal coefficients are extremely similar to the estimated coefficient values. It is also interesting to note that when we compare the pre- and post-crisis periods, the optimal and estimated coefficient values for the interest rate smoothing and the interest rate spread are larger for the more recent period. This should not be too surprising as the degree of uncertainty in the latter period would have been greater, which would have promoted a higher degree of interest rate smoothing. In addition, given the growing importance of the central bank response to financial frictions, following the onset of the crisis, we note that the value of ϕ_{ω} has increased slightly in the latter subsample (in both the estimated and optimal cases).[23]

5.6 The sacrifice ratio of the optimal monetary policy rules

Monetary policy actions that seek to reduce inflationary pressure may contribute towards reduced levels of economic activity and employment. In what follows, we calculate the sacrifice ratio, which is the relative decline in output for a reduction in inflation, for the different optimal monetary policy rules. In addition, we also make use of the sacrifice ratios that are due to the estimated coefficients.[24]

Figure 4 presents the results of the sacrifice ratio calculations, where 'Optimal-1' and 'Optimal-2' represent the sacrifice ratios for the optimal monetary policy rule coefficients that are contained for the entire sample in the third and fourth column in Table 2. Thereafter, the sacrifice ratio for the estimated monetary policy rule coefficients have been labelled 'Estimated' in the graph below. There are notable differences in the size and adjustment process across the two sets of optimal monetary policy rules, where the optimal rule that is contained in the third column in Table 2 would generate the least desirable sacrifice ratio. In this case, the most desirable outcome is provided by the optimal monetary policy rule that is presented in the fourth column of the table,

[22] This would be consistent with the findings of Alpanda et al. (2010).

[23] Note that the coefficient values for the estimated coefficients and the optimal coefficients in the third column are extremely similar, which would suggest that the central bank has been pursuing a near optimal monetary policy rule following the onset of the Global Financial Crisis. However, as shown in the online appendix, these differences do nevertheless result in a gap in the sacrifice ratio, when comparing the result that is produced by the estimated and optimal coefficients in the post-crisis subsample.

[24] In the early literature, the sacrifice ratio was obtained from the relationship between output and inflation that was based on estimates for the Philips curve (c.f. Okun 1978; Gordon et al. 1982). More recently, Ball (1994) and Cecchetti and Rich (2001) use monetary policy impulse response functions that are derived from vector autoregressive (VAR) models to estimate the sacrifice ratio.

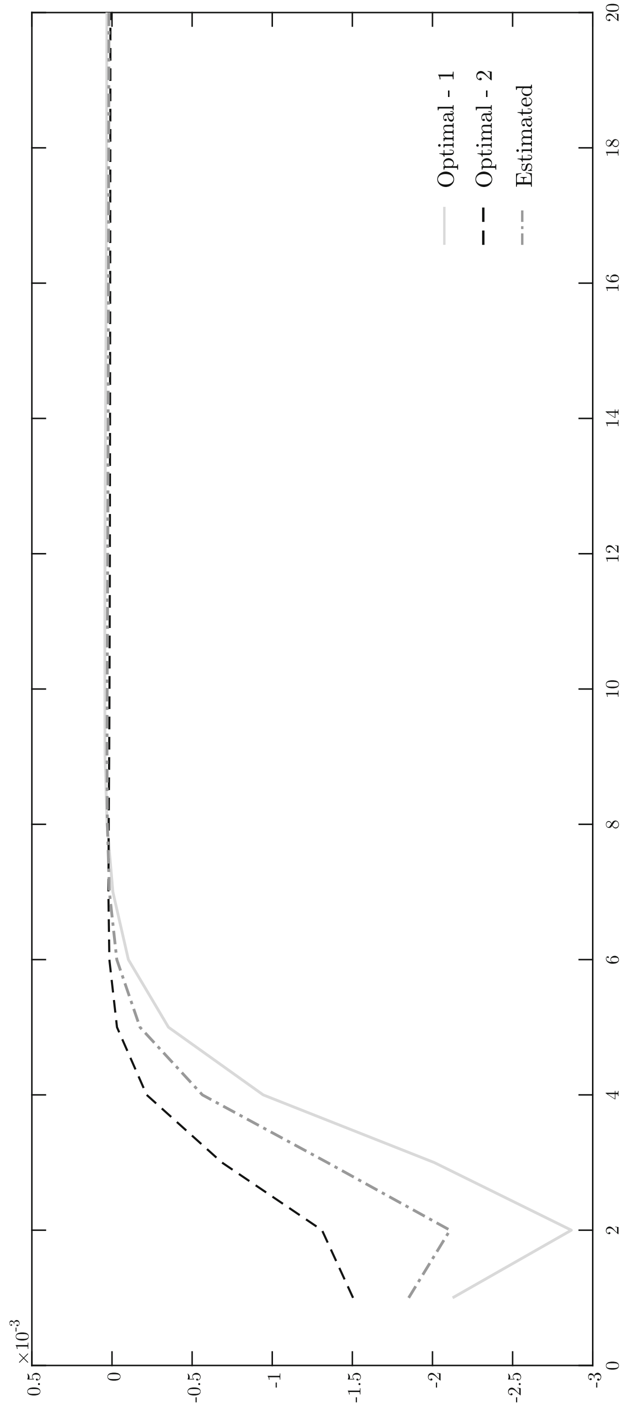

Fig. 4 Sacrifice ratio for the optimal monetary policy rules and the estimated policy rule

where output is associated with a relatively large weight and interest rate smoothing has a relatively small weight for the λ_ι parameters.

When considering these results in conjunction with the similarity of the coefficient values for the optimal and estimated cases (as reported in Table 2), we note once again that it would appear as if the BOU has conducted near optimal model policy over the entire sample. After breaking the sample down into the two subsamples the difference in the sacrifice ratios (when comparing the optimal and estimated cases) is larger in the post-crisis subsample due to three main possible reasons.[25] Firstly, the global financial crisis created conditions of greater uncertainty about the role of monetary policy. Secondly, the post-crisis period included an episode where inflation rose to almost 31% in October 2011 (while in 2015 it was at 5.41%). And thirdly, the adjustment to a new inflation-targeting monetary policy framework towards the end of 2011. Together these features would have made it more challenging to conduct near optimal monetary policy in the latter subsample; however, the gap in the sacrifice ratio between what would have been provided by actual and optimal policy is nevertheless eliminated after six quarters.

6 Conclusion

The financial sector affects several sectors of an economy, where imperfections could give rise to macroeconomic instability. Following the recent global financial crisis, research on business cycles in many developed and some advanced emerging market economies has considered the inclusion of financial frictions in structural macroeconomic models. This paper extends this literature to the economies of LICs, where the financial structure differs to that of developed and emerging market counterparts. The paper estimates a small open-economy DSGE model with financial frictions using Ugandan data. Financial frictions are introduced with the aid of the framework that has been proposed by Curdia and Woodford (2010), which makes use of heterogeneous households for savers and borrowers.

The results suggest that the key posterior parameter estimates are largely consistent with the values that are found in the general literature, where the monetary authority reacts to an increase in lending spreads by lowering the policy rate. Consequently, the level of borrowing rises, along with output and inflation, while the exchange rate appreciates. When the dynamics of the model without financial frictions are compared to the one that incorporates these frictions, the results suggest that as spreads widen, the level of borrowing declines by a smaller magnitude in the model with financial frictions. Furthermore, these results also suggest that the central bank would lower the policy interest rate by a larger magnitude in response to an increase in the spread when financial frictions are included in the central bank response function.

When considering the effect of a monetary policy innovation in the model with financial frictions, we note that the response of the variables broadly matches the monetary policy transmission literature. For example, a monetary policy shock leads to an increase in the lending rate, an increase in non-performing loans, a decrease in

[25] The results of these sacrifice ratios is contained in the online appendix.

borrowing, a decline in of the output gap, a fall in the rate of inflation and an appreciation of the exchange rate. The results for the historical decompositions may also be used to show the importance of shocks to non-performing loans in the composition of output and inflation. In addition, we note that these shocks were particularly important over the period of the global financial crisis, while cost-push shocks initiated a rapid rise in inflation during 2011–2012.

The results of the investigation into the optimal monetary policy rule suggest that the estimated coefficients are comparable to the optimal counterparts. This would imply that the optimal response from the central bank is not significantly different to the current response. In addition, it is also worth noting that in all cases, the value of the coefficient for the response to changes in the interest rate spread is substantially different from zero, which would suggest that the central bank should respond to changes in the interest rate spread if it is to reduce macroeconomic volatility. These results are also considered in light of the sacrifice ratios, where we note that the central bank may want to consider slightly more aggressive responses to changes in output and inflation, which may provide lower macroeconomic volatility.

References

Alpanda S, Kotzé K, Woglom G (2010) Should central banks of small open economies respond to exchange rate fluctuations? the case of South Africa. ERSA working paper, no. 174

An S, Schorfheide F (2007) Bayesian analysis of DSGE models. Econom Rev 26(2–4):113–172

Baldini A, Benes J, Berg A, Dao MC, Portillo RA (2015) Monetary policy in low income countries in the face of the global crisis: a structural analysis. Pac Econ Rev 20(1):149–192

Ball L (1994) What determines the sacrifice ratio? In: Monetary policy. The University of Chicago Press, pp 155–193

Berg A, Gottschalk J, Portillo R, Zanna L-F (2010a) The macroeconomics of medium-term aid scaling-up scenarios. IMF working papers, pp 1–45

Berg A, Unsal DF, Portillo R (2010b) On the optimal adherence to money targets in a new-Keynesian framework: an application to low-income countries. IMF working papers (no. 10-134), Washington, International Monetary Fund

Bernanke BS, Gertler M, Gilchrist S (1999) The financial accelerator in a quantitative business cycle framework. Handb Macroecon 1:1341–1393

Blanchard O, Dell Ariccia G, Mauro P (2010) Rethinking macroeconomic policy. J Money Credit Bank 42(s1):199–215

Brooks SP, Gelman A (1998) General methods for monitoring convergence of iterative simulations. J Comput Graph Stat 7(4):434–455

Calvo GA (1983) Staggered prices in a utility-maximizing framework. J Monet Econ 12(3):383–398

Cecchetti SG, Rich RW (2001) Structural estimates of the US sacrifice ratio. J Bus Econ Stat 19(4):416–427

Curdia V, Woodford M (2010) Credit spreads and monetary policy. J Money Credit Bank 42(s1):3–35

Fernández-Villaverde J (2010) The econometrics of DSGE models. SERIEs 1(1–2):3–49

Gali J, Monacelli T (2005) Monetary policy and exchange rate volatility in a small open economy. Rev Econ Stud 72(3):707–734

Gordon RJ, King SR, Modigliani F (1982) The output cost of disinflation in traditional and vector autoregressive models. Brook Pap Econ Act 1:205–244

Gray DF, García C, Luna L, Restrepo J (2011) Incorporating financial sector risk into monetary policy models: application to Chile. IMF working papers, pp 1–34

Justiniano A, Preston B (2010) Monetary policy and uncertainty in an empirical small open-economy model. J Appl Econom 25(1):93–128

Kiyotaki N, Moore J et al (1997) Credit chains. J Polit Econ 105(21):211–248

McCulley P, Toloui R (2008) Chasing the neutral rate down: Financial conditions, monetary policy, and the Taylor rule. Global Central Bank Focus, pp 2002–2008
Mishkin FS (1996) The channels of monetary transmission: lessons for monetary policy. Technical report, National Bureau of Economic Research
Mishra P, Montiel PJ, Spilimbergo A (2010) Monetary transmission in low income countries. IMF working papers, pp 1–42
Modigliani F, Miller MH (1958) The cost of capital, corporation finance and the theory of investment. Am Econ Rev 261–297
Okun AM (1978) Efficient disinflationary policies. Am Econ Rev 68(2):348–352
Patinkin D (1956) Money, interest, and prices: an integration of monetary and value theory. Row, Peterson, Evanston
Quadrini V (2011) Financial frictions in macroeconomic fluctuations. FRB Richmond Econ Q 97(3):209–254
Rudebusch GD (2002) Term structure evidence on interest rate smoothing and monetary policy inertia. J Monet Econ 49(6):1161–1187
Schmitt-Grohé S, Uribe M (2003) Closing small open economy models. J Int Econ 61(1):163–185
Steinbach R, Du Plessis S, Smit B (2014) Monetary policy and financial shocks in an empirical small open-economy DSGE model. Technical report, EcoMod
Stiglitz JE, Weiss A (1981) Credit rationing in markets with imperfect information. Am Econ Rev 71(3):393–410
Svensson LE (2012) The relation between monetary policy and financial policy. Int J Central Bank 8(S1 s 293):295
Taylor JB (1993) Discretion versus policy rules in practice. In: Carnegie–Rochester conference series on public policy, vol 39. Elsevier, pp 195–214
Taylor JB (2009) The financial crisis and the policy responses: an empirical analysis of what went wrong. Technical report, National Bureau of Economic Research
Tobin J (1969) A general equilibrium approach to monetary theory. J Money Credit Bank 1(1):15–29
Tumusiime-Mutebile E (2012) Monetary policy statement. Technical report, Bank of Uganda
Vlcek MJ, Roger MS (2012) Macrofinancial modeling at central banks: recent developments and future directions (no 12–21). International Monetary Fund
Vredin A (2015) Inflation targeting and financial stability: providing policymakers with relevant information. BIS working paper 503, Bank of International Settlements
Woodford M (2012) Inflation targeting and financial stability. Technical report, National Bureau of Economic Research