Monetary policy and financial shocks in an empirical small open-economy DSGE model

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Abstract

In the aftermath of the global financial crisis in 2008, central banks across the globe reduced their policy rates by unprecedented margins. At the same time, commercial banks were increasing their lending rates in order to protect their crisis-induced fragile balance sheets. To a large extent, these opposing reactions reduced the efficacy of monetary policy in accommodating the substantial decline in aggregate demand seen at the time. In this paper, a standard small open economy New Keynesian DSGE model of the South African economy is extended to incorporate lending rates of commercial banks which deviate from the policy rate, especially in times of financial stress. Within the context of this structural model, the optimal reaction of the SARB to these lending rate deviations – or credit spreads – is analysed.

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Contents

List of Tables

List of Figures

1 Introduction

During the build-up to the global financial crisis, most macroeconomic models (especially those used for forecasting by central banks[1]) had to a large extent excluded the financial sector. The models of the day generally had only one interest rate, which was the policy rate, and fluctuations of actual market interest rates around the policy rate were not accounted for, as the role of financial intermediation was deemed to be irrelevant for the transmission of monetary policy (Blanchard et al., 2010). Up until that point, developments in modern macroeconomics and finance had been largely disjointed, and, as a result, policymakers were neither able to coherently assess nor fully comprehend the macroeconomic implications of the financial instability induced by the crisis.[2]

Fortunately, recent years have seen both significant interest and progress in closing this chasm between modern macroeconomics and finance.[3] As an example within the DSGE literature, Goodfriend and McCallum (2007) adapt the standard New Keynesian framework by assuming that households need to borrow from banks in order to consume. The banking sector is modelled as a Cobb-Douglas loan "production function" with factor inputs being a combination of collateral and loan monitoring. Collateral is represented by the effective value of capital owned by households, and the loan monitoring is done by the proportion of labour being supplied to the banking sector by households. Similarly, Christiano et al. (2010) augment the standard DSGE framework to include a financial sector, where banks pay interest on household deposits, and in turn use these deposits in order to provide loans to firms and entrepeneurs. These studies assume that banks operate in a perfectly competitive environment and are therefore not able to set loan and deposit rates. More recent studies, like Andrés and Arce (2012), Aslam and Santoro (2008), Gerali et al. (2010) allow for monopolistic competition within the banking sector, which allows banks to set their deposit and loan rates. In addition, the loan dynamics are further enriched as households accumulate housing stock, which also serves as collateral when borrowing.

With regard to the monetary policy transmission mechanism, the studies discussed above accommodate two competing effects for the role played by the banking sector in the transmission of monetary policy: a "banking accelerator" effect; and a "banking attenuator" effect. The former follows from the notion that expansionary monetary policy stimulates employment and output, and hence the value of collateral in the economy. The rise in the value of collateral leads to a fall in the lending premium and therefore raises the demand for loans. The attenuator effect has the opposite impact, as banks need to increase their employment to meet the rise in loan demand. An increased wage bill translates into higher marginal costs on behalf of the bank, which raises the lending premium and therefore counteracts the initial expansionary effect. Goodfriend and McCallum (2007) find that for reasonable calibrations, either effect may dominate, and banks may subsequently either amplify or dampen monetary policy shocks when compared to a benchmark model without a banking sector.

Turning from the role of the financial sector in amplifying monetary policy shocks, the global financial crisis of 2008 ignited a rather different debate: the role of monetary policy in curtailing the impact of financial shocks. The aftermath of the crisis saw central banks across the globe reducing their policy rates by unprecedented margins. At the same time, commercial banks were increasing their lending rates in order to protect their crisis-induced fragile balance sheets. To a large extent, these opposing reactions reduced the efficacy of standard expansionary monetary policy in accommodating the substantial decline in aggregate demand seen at the time. As a result, the appropriate reaction of monetary policy to the increase in lending rates, or rather widening credit spreads, was at the centre of attention. Both McCulley and Toloui (2008) and Taylor (2008) suggested that the central bank follow a Taylor rule that yields a one-for-one reduction in the policy rate in response to increases in credit spreads. However, from the vantage point of a structural model, Cúrdia and Woodford (2010) found that a less than one-for-one

[1] See Tucker (2009).
[2] See Blanchflower (2009).
[3] See Cochrane (2006) for a compilation of studies that focus on the "intersection" of macroeconomics and finance.

reduction would be optimal. In their model, households are assumed to be either borrowers or savers, which creates a role for financial intermediation as banks take deposits from saving households, convert these deposits to loans, and then lend them to borrowing households at a spread over the deposit rate. However, it is assumed that a proportion of loans are not repaid in the end, and that the spread is an increasing function of this proportion of non-performing loans. Hence, the financial shock originates from an increase in non-performing loans which then leads to higher credit spreads.

To date, the majority of the literature that has aimed to incorporate financial frictions into DSGE models has been within the context of a closed economy, where parameters have mostly been calibrated. This paper incorporates the Cúrdia and Woodford (2010) framework into the small open-economy model developed in du Plessis et al. (2014). As an additional contribution to the existing literature, the model parameters are estimated using a dataset of 17 observable variables, which includes two variables that are specifically related to financial intermediaries: the effective lending rate and the ratio of non-performing loans to total assets of the South African banking sector. The suggestions of McCulley and Toloui (2008), Taylor (2008) and Cúrdia and Woodford (2010), *i.e.* that the central bank should respond to changes in credit spreads, are then analysed within the small open-economy context of South Africa. This is done through a loss-function comparison where the central bank includes credit spread deviations in a Taylor rule setting, as opposed to following the standard Taylor rule that focuses only on inflation and the output gap.

The remainder of the paper is laid out as follows: Section 2 discusses the inclusion of a banking sector in the existing model. Thereafter, issues relating to the data as well as the estimation results are discussed in Section 3. The macroeconomic reaction to a financial shock is portrayed in Section 4, while the optimal response to such is shock is calculated in Section 5. Finally, Section 6 concludes.

2 The model

The general structure of the model largely builds on the small open economy model of Chapter **??**. However, in order to analyse the role of monetary policy in the face of financial disturbances, two key extensions to the model are introduced: (1) heterogeneous households; and (2) financial intermediaries. These extensions broadly follow Cúrdia and Woodford (2009, 2010) where, based on their differing degrees of impatience to consume, households are classified as either savers or borrowers. In turn, this heterogeneity creates a role for financial intermediation in the model.

2.1 Heterogeneous households

The economy is populated by a mass of savers s and borrowers b, where the marginal utility of savers with respect to consumption is assumed to be lower than that of borrowers. In addition, the spending by these households in every period is allowed to differ from their income. As such, *savers* may either purchase risk-free government bonds or deposit funds at the financial intermediary if their income were to exceed their expenditure, while *borrowers* may borrow funds from the intermediary if their expenditure were to exceed their income. In turn, government bonds and deposits are remunerated at the prevailing gross policy rate R_t, while funds are borrowed at the gross lending rate R_t^b, where $R_t^b > R_t$. Furthermore, it is assumed that the households' types (*i.e.* saver or borrower) may change over time. Accordingly, their types evolve as two-state Markov chains, where in every period an event occurs with probability $1-\chi$ that renders the household eligible for the draw of a new type. At the draw, type s is drawn with probability p_s and type b with probability p_b, where $p_s + p_b = 1$. More specifically, χ is set to 0.975 and $p_s = p_b = 0.5$, such that there is an equal share of savers and borrowers and, on average, a household is expected to be eligible for the draw of a new type once every 10 years.

It is assumed that households maximise their expected discounted utility as follows:

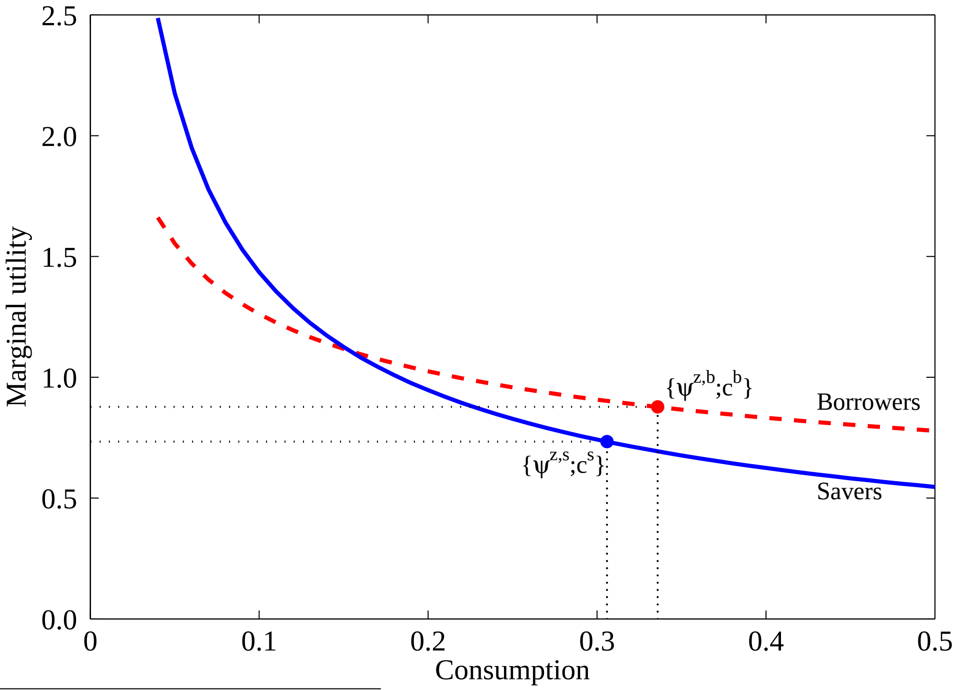
$$E_0 \sum_{t=0}^{\infty} \beta^t \left[u^{\tau_t(i)} \left(C_t(i); \xi_t^c\right) - v^{\tau_t(i)} \left(h_t(i); \xi_t^h\right) \right], \tag{1}$$

where $\tau_t(i) \in \{s, b\}$, while the utility derived from consumption and disutility from supplying labour are respectively given by:

$$u^{\tau_t(i)} \left(C_t(i); \xi_t^c\right) \equiv \xi_t^c \frac{\left(C_t(i) - b_\tau C_{t-1}^\tau\right)^{1-\sigma_\tau}}{1-\sigma_\tau} \qquad \text{and} \qquad v^{\tau_t(i)} \left(h_t(i); \xi_t^h\right) \equiv \xi_t^h A_L \frac{h_t(i)^{1+\sigma_L}}{1+\sigma_L}. \tag{2}$$

The degree of habit formation is denoted by b_τ, σ_τ is the (inverse) intertemporal elasticity of substitution, A_L pins down labour supply in the steady state and σ_L represents the (inverse) Frisch elasticity[4]. Moreover, it is assumed that $\sigma_s > \sigma_b$ and $b_s > b_b$, such that savers' expenditure is less sensitive to changes in interest rates than that of borrowers. This further implies that in equilibrium the marginal utility of consumption for savers is less than for borrowers, as can be seen in Figure 1.[5] Finally, the aggregate preference shocks ξ_t^c and ξ_t^h in Equation (2) affect the preferences of both type s and b households.[6]

Figure 1: Marginal utilities of consumption



[4]The functional form of the utility function differs from Cúrdia and Woodford (2009) with respect to habit formation. In their specification, household i's consumption does not depend on a measure of lagged consumption. The specification chosen here assumes that household's exhibit habit formation with respect to the aggregate consumption of their current type in $t-1$.

[5]Figure 1 is derived from the parameter values in Section 3.

[6]In order to ensure that households' expected marginal utilities of income do not diverge as a result of their differing type histories, it is assumed that households are able to sign state-contingent insurance contracts with one another which insures them against the risks (aggregate and idiosyncratic) associated with the random draw of a new type. However, households may only receive these insurance transfers periodically. For convenience, it is assumed that households may receive these transfers coincides with them becoming eligible for the draw of a new type. In addition, the fact that households have access to this insurance contract facilitates model aggregation.

Let $A_t(i)$ denote the beginning-of-period domestic net financial wealth of household i, as follows:

$$A_t(i) = \left[B_{t-1}(i)\right]^+ R_{t-1} + \left[B_{t-1}(i)\right]^- R^b_{t-1} + \Pi^{int}_t \tag{3}$$

where B_{t-1} is its (domestic) net financial wealth at the end of period $t-1$, $\left[B\right]^+ \equiv \max(B,0)$ and $\left[B\right]^- \equiv \min(B,0)$, such that positive asset balances are remunerated at the gross policy rate R_{t-1}, while the (gross) borrowing rate R^b_t applies to negative balances. Hence, if D_t and B^g_t denote aggregate deposits and risk-free government bonds at the end of period t, while L_t denotes aggregate borrowing from financial intermediaries, then from Equation (3) it follows that:

$$D_t + B^g_t = \int_{\mathscr{S}_t} A_t(i)di \quad \text{and} \quad L_t = -\int_{\mathscr{B}_t} A_t(i)di, \tag{4}$$

where $\mathscr{S}_t$ and $\mathscr{B}_t$ represent the sets of households for whom $A_t(i) \geq 0$ and $A_t(i) < 0$, respectively. Moreover, households are assumed to be the owners of financial intermediaries and, as a result, the profits from this sector, Π^{int}_t, are distributed equally among all households in Equation (3).

In addition to domestic financial assets, households may also invest in foreign risk-free bonds, B^*_t. However, as in Benigno (2009), the interest rate on the foreign bond is subjected to a risk premium that is an increasing function of the domestic economy's indebtedness in the international asset market, as measured by its net foreign asset position:

$$a^*_t \equiv \frac{S_t B^*_t}{z_t P^d_t}, \tag{5}$$

where S_t is the nominal exchange rate, z_t represents the economy-wide real stochastic trend, and P^d_t is the domestic price deflator. Schmitt-Grohé and Uribe (2003) show that the inclusion of this debt-elastic risk premium is crucial for the determination of a well-defined steady state in small open economy models. Consequently, it is assumed that the risk premium has the following functional form

$$\Phi(a^*_t, \tilde{\phi}_t) = \exp\left\{-\tilde{\phi}_a(a_t - a) + \tilde{\phi}_t\right\}. \tag{6}$$

where $\tilde{\phi}_t$ represents an AR(1) shock to the risk premium, while in the steady state, the risk premium has the property $\Phi(0,0) = 1$.[7]

Given the above exposition of its asset holdings, the household budget constraint may be formulated as follows:

$$\begin{aligned} B_t(i) + S_t B^*_t(i) &= A_t(i) + S_t B^*_{t-1}(i) R^*_{t-1} \Phi\left(a^*_{t-1}, \tilde{\phi}_{t-1}\right) + W_t(i)h_t(i) + R^k_t K_{t-1}(i) \\ &- P^c_t C_t(i) - P^i_t I_t(i) + \Pi_t - T_t. \end{aligned} \tag{7}$$

Accordingly, households have at their disposal their beginning-of-period financial wealth which, depending on their type history, may be positive or negative, as well as foreign bonds. In addition, they earn wages $W_t(i)$ and return R^k_t on the labour and capital they supply to firms, as well as profits Π_t from firm ownership. Their income, combined with their beginning-of-period financial wealth, enables them to purchase nominal consumption and investment goods and pay lump sum taxes. If the household is of type s, its resources may exceed its expenditure in period t, and it will either deposit the difference with the financial intermediary, purchase a risk-free domestic government bond, a foreign bonds, or all of the above. If the household is of type b, its expenditure may exceed its resources, and it will borrow the difference from the financial intermediary. In addition, households are assumed to own the capital

[7] For simplicity it is assumed that only savers participate in international capital markets, which in turn ensures that uncovered interest rate parity (UIP) holds between domestic and foreign policy rates only.

stock $K_t(i)$, and given their investment decision, the aggregate capital stock accumulates as follows:

$$K_t = (1-\delta)K_{t-1} + \xi_t^i I_t - S\left(\frac{I_t}{K_{t-1}}\right), \tag{8}$$

where δ is the rate of capital depreciation, while

$$S\left(\frac{I_t}{K_{t-1}}\right) = \frac{\phi_k}{2}\left(\frac{I_t}{K_{t-1}} - \delta^*\right)^2 K_{t-1}, \tag{9}$$

and $\delta^* = \frac{I}{K}$ such that in steady state, $S(\cdot) = S'(\cdot) = 0$ and $S''(\cdot) \equiv \phi_k$, with $\phi_k > 0$.[8] Moreover, similar to Greenwood et al. (1988), ξ_t^i is an investment specific technology shock that follows an AR(1) process.

Optimality conditions Optimisation of the household's utility function, Eq. (1), subject to the budget constraint and capital's law of motion, Eqs. (7) and (8), yields the following set of first-order conditions with respect to each of the choice variables for households of type $\tau \in \{s,b\}$:

Consumption, c_t^τ

$$\xi_t^c\left(c_t^\tau - b_\tau c_{t-1}^\tau \frac{1}{\mu_t^z}\right)^{-\sigma_\tau} - \beta b_\tau E_t \xi_{t+1}^c\left(c_{t+1}^\tau \mu_{t+1}^z - b c_t^\tau\right)^{-\sigma_\tau} - \psi_t^{z,\tau}\frac{P_t^c}{P_t^d} = 0 \tag{10}$$

Investment, i_t^τ

$$P_t^{k',\tau}\left[\xi_t^i - \phi_k\left(\frac{i_t^\tau}{k_{t-1}^\tau}\mu_t^z - \delta^*\right)\right] - \frac{P_t^i}{P_t^d} = 0 \tag{11}$$

Capital stock, k_t^τ

$$\begin{aligned}&\beta\chi E_t \psi_{t+1}^{z,\tau} P_{t+1}^{k',\tau}\left[(1-\delta) - \frac{\phi_k}{2}\left(\frac{i_{t+1}^\tau}{k_t^\tau}\mu_{t+1}^z - \delta^*\right)^2 + \phi_k\left(\frac{i_{t+1}^\tau}{k_t^\tau}\mu_{t+1}^z - \delta^*\right)\frac{i_{t+1}^\tau}{k_t^\tau}\mu_{t+1}^z\right] \\ &-\psi_t^{z,\tau}P_t^{k',\tau}\mu_{t+1}^z + \beta\chi E_t \psi_{t+1}^{z,\tau} r_{t+1}^k + \beta \sum_{\tau'\in\{b,s\}} (1-\chi) p_{\tau'} \psi_{t+1}^{z,\tau'} f_t = 0\end{aligned} \tag{12}$$

where

$$f_t = r_{t+1}^k + P_{t+1}^{k',\tau'}\left[(1-\delta) - \frac{\phi_k}{2}\left(\frac{i_{t+1}^{\tau'}}{k_t^{\tau'}}\mu_{t+1}^z - \delta^*\right)^2 + \phi_k\left(\frac{i_{t+1}^{\tau'}}{k_t^{\tau'}}\mu_{t+1}^z - \delta^*\right)\frac{i_{t+1}^\tau}{k_t^{\tau'}}\mu_{t+1}^z\right] \tag{13}$$

Borrowing, l_t

$$-\psi_t^{z,b} + \beta E_t\left[\frac{R_t^b}{\mu_{t+1}^z \pi_{t+1}}\left\{\left[\chi + (1-\chi)p_b\right]\psi_{t+1}^{z,b} + (1-\chi)p_s\psi_{t+1}^{z,s}\right\}\right] = 0 \tag{14}$$

Domestic deposit and bond holdings, $(d_t + b_t)$

$$-\psi_t^{z,s} + \beta E_t\left[\frac{R_t}{\mu_{t+1}^z \pi_{t+1}}\left\{(1-\chi)p_b\psi_{t+1}^{z,b} + \left[\chi + (1-\chi)p_s\right]\psi_{t+1}^{z,s}\right\}\right] = 0 \tag{15}$$

[8] The functional form of the capital adjustment cost function follows Avdjiev (2011), which builds on earlier work by Hayashi (1982) and Abel and Blanchard (1983), amongst others.

Foreign bond holdings, b_t^*

$$-\psi_t^{z,s}+\beta E_t\left[\frac{S_{t+1}}{S_t}\frac{R_t^*\Phi(a_t^*,\tilde{\phi}_t)}{\mu_{t+1}^z\pi_{t+1}}\left\{(1-\chi)\,p_b\psi_{t+1}^{z,b}+[\chi+(1-\chi)\,p_s]\,\psi_{t+1}^{z,s}\right\}\right]=0 \tag{16}$$

where all trending variables have been rendered stationary, as represented by their lower case counterparts, and $\psi_t^{z,\tau}=z_tP_t^d\upsilon_t^\tau$ is the stationary Lagrange multiplier. In addition, the log-linearised combination of the first-order conditions for domestic assets and foreign bond holdings, Eqs. (15) and (**??**), yield the UIP condition

$$\hat{R}_t-\hat{R}_t^*=E_t\hat{S}_{t+1}-\hat{S}_t-\tilde{\phi}_a\hat{a}_t+\hat{\tilde{\phi}}_t, \tag{17}$$

such that an increase (decrease) in the net foreign asset position of the domestic economy – *ceteris paribus* – leads to an appreciation (depreciation) of its currency.

Evolution of household borrowing At the beginning of every period, a fraction χ of borrowers are not eligible for the draw of a new type and hence they remain borrowers with existing real debt to the value of $\chi l_{t-1}R_{t-1}^b/(\mu_t^z\pi_t^d)$. From the fraction $1-\chi$ of borrowers who are in the draw, p_b remain borrowers as well, with existing debt that amounts to $(1-\chi)p_bl_{t-1}R_{t-1}^b/(\mu_t^z\pi_t^d)$. In turn, a fraction $(1-\chi)$ of savers became eligible for the draw of a new type, where they learn that they are now type b. These new borrowers, who were savers in period $t-1$, own assets to the value of $(1-\chi)p_b\left[\left(d_{t-1}+b_{t-1}^g\right)R_t+S_tb_{t-1}^*R_{t-1}^*\Phi(\cdot)\right]/(\mu_t^z\pi_t^d)$. As a result, end-of-period borrowing is given as:

$$\begin{aligned} b_t &= \left[\chi+(1-\chi)\,p_b\right]l_{t-1}R_{t-1}^b-(1-\chi)\,p_b\left[\left(d_{t-1}+b_{t-1}^g\right)R_t+S_tb_{t-1}^*R_{t-1}^*\Phi(\cdot)\right]/\left(\mu_t^z\pi_t^d\right) \\ &+ p_b\left[\gamma_t^{c,d}c_t^b+\gamma_t^{i,d}i_t^b-w_t^bh_t^b-r_t^k\frac{k_{t-1}^b}{\mu_t^z}-\Pi_t^r+\tau_t\right] \end{aligned} \tag{18}$$

where $\Phi(\cdot)=\Phi\left(a_{t-1}^*,\tilde{\phi}_{t-1}\right)$, while $\gamma_t^{c,d}=P_t^c/P_t^d$ and $\gamma_t^{i,d}=P_t^i/P_t^d$

2.2 Financial intermediaries

Financial intermediaries take real deposits d_t from households and convert them into real loans l_t. However, the intermediary makes provision for the fact that a fraction $\zeta_t(l_t)$ of loans will not be repaid. As such, the period t real profits of financial intermediaries may be expressed as:

$$\Pi_t^{int,r}=d_t-l_t-\zeta_t(l_t), \tag{19}$$

where $\zeta_t(l_t)=\zeta_tl_t^{1+\eta_\zeta}$. Moreover, it is assumed that the activities of financial intermediaries are confined to the domestic economy. This assumption obviously simplifies the analysis, but it is also justified by the relatively low foreign currency exposure of the South African banking sector, where foreign currency deposits as a ratio to total liabilities averaged 4.5 per cent from January 2008 to December 2012, while the ratio of foreign currency loans to total assets averaged 5.8 per cent over the same period.[9]

Although loans extended in period t had a value of $l_t+\zeta_t(l_t)$, eventual repayment of these loans in $t+1$ will only amount to $l_tR_t^b$, which equals the remuneration on deposits of d_tR_t. Let the gross spread by which the financial intermediary sets the loan rate be denoted by ω_t, such that

$$R_t^b=\omega_tR_t. \tag{20}$$

Assuming financial intermediaries are able to lend at the spread ω_t, optimising profits in Equation (19)

[9]These ratios were taken from the South African Reserve Bank's BA900 returns.

by choosing l_t yields the following first order condition for the gross spread:

$$\omega_t = 1 + (1+\eta_\zeta)\zeta_t l_t^{\eta_\zeta} + \eta_\Theta \Theta_t l_t^{\eta_\Theta - 1}. \tag{21}$$

Accordingly, the magnitude of the spread between the loan and deposit rate is an increasing function of both the rate of non-performing loans ζ_t, and the volume of loans l_t (when $\eta_\Theta > 0$). Here the positive role played by borrowing in the determination of the credit spread reflects the additional resource cost incurred by the financial intermediary when lending volumes increase. Hence, increased lending activity implies a greater need for loan origination and monitoring, which, in turn, are costly for the financial intermediary. Moreover, while Cúrdia and Woodford (2009) assume that ζ_t follows an exogenous process, in this paper it is assumed that non-performing loans are a function of real economic conditions:

$$\zeta_t = \zeta_{t-1}^{\rho_\zeta} y_t^{-\theta_\zeta} \varepsilon_{\zeta,t}, \tag{22}$$

where $\theta_\zeta > 0$ and $\varepsilon_{\zeta,t}$ is an exogenous shock. The link between loan performance and economic activity has been well documented in the literature.[10] During economic downturns, the balance sheets of borrowers are adversely affected by falling asset prices and rising unemployment. These impaired balance sheets affect the ability of borrowers to repay their loans which, in turn, leads to an increase in non-performing loans on the balance sheets of financial intermediaries. Moreover, the inclusion of this link between non-performing loans and real economic activity introduces the so-called adverse feedback loop into the model, whereby "weakening real and financial economic conditions become mutually reinforcing.“ (Bernanke, 2009). Hence, the increase in non-performing loans caused by the deteriorating real economy leads to a higher lending spread ω_t. Higher lending rates, in turn, exacerbate the slowdown in economic activity, which translates into further loan losses on the balance sheets of financial intermediaries.

2.3 Government

In every period, the government finances its expenditure by issuing new one-period bonds and raising taxes. Its period expenses consist of nominal general government expenditure $P_t^d G_t$ and also the repayment of maturing one-period bonds. Consequently, the real (stationary) budget constraint of the government is expressed as follows:

$$b_t^g + \tau_t = \ell_t + g_t, \tag{23}$$

where the government's total liabilities, ℓ_t, is defined as:

$$\ell_t = \left(b_{t-1}^g R_{t-1}\right) / \left(\mu_t^z \pi_t^d\right). \tag{24}$$

In order to ensure dynamic stability, where inflation does not emerge as a fiscal phenomenon (see Leeper, 1991) , it is assumed that taxation by government is determined by the deviation of its outstanding liabilities from their steady state values:

$$\tau_t = \psi_0 + \psi_1 (\ell_t - \ell) \tag{25}$$

Accordingly, Equation (25) implies that taxes cannot be set independently from the level of outstanding government debt. This, in turn, rules out any possibility of an explosive path for government debt. Finally, government expenditure is assumed to follow an AR(1) process.

[10]See, for instance, Beck et al. (2013), Glen and Mondragón-Vélez (2011) and Nkusu (2011).

2.4 The central bank

It is assumed that the central bank sets the policy rate in response to the expected deviation of year-on-year CPI inflation $\hat{\pi}^{c,4}_{t+1}$ from its target as well as the current quarter's change in the price level, $\hat{\pi}^c_t$. In addition, the central bank also takes into account the current level and rate of change in output. Consequently, the monetary policy rule is specified as follows:

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1-\rho_R)\left[\hat{\bar{\pi}}^c_t + \phi_\pi \left(\hat{\pi}^{c,4}_{t+1} - \hat{\bar{\pi}}^c_t\right) + \phi_{\Delta\pi}\hat{\pi}^c_t + \phi_y \hat{y}_t + \phi_{\Delta y}\Delta\hat{y}_t\right] + \varepsilon^R, \tag{26}$$

where year-on-year CPI inflation is defined as $\hat{\pi}^{c,4}_t = \frac{1}{4}\prod_{j=1}^{4}\pi_{t+1-j}$.

2.5 Aggregate demand

Finally, clearing in the domestic final goods market requires that the supply of the final good firm matches the demand from households, government and the export market, after taking account of the additional adjustment costs on L-period bonds and money that are paid in terms of output:

$$y_t = \varepsilon_t \left(\frac{k^s_t}{\mu^z_t}\right)^{\alpha} H_t^{1-\alpha} - \phi, \tag{27}$$

where $y_t = (p_s c^s_t + p_b c^b_t) + (p_s i^s_t + p_b i^b_t) + g_t + nx_t$.[11] The remainder of the model structure is similar to du Plessis et al. (2014), and the entire set of log-linearised equations is in the Appendix.

3 Estimation

3.1 Data

In addition to the fifteen observable domestic and international macro-economic time series used to estimate the model in Chapter **??**, two additional variables are now included that relate to the South African banking sector. Firstly, a measure of the effective interest rate paid on outstanding debt is included, where the difference between this lending rate and the Repo rate yields the (observable) lending spread ω_t. This effective lending rate is approximated by dividing the monthly interest income that South African banks receive from mortgage loans, credit-card debt, instalment sales and overdrafts by the end-of-month balances of these various loan books.[12] The second additional variable – a measure of the ratio of non-performing loans to total lending by South African banks – allows for a quantification of the impact that non-performing loans (ζ_t) have on lending spreads in Equation (21), which is a key propagation channel in the model.[13] Moreover, the inclusion of non-performing loans as an observable variable assists in the quantification of the interrelationship between ζ_t and y_t in Equation (22) – the channel through which the adverse feedback loop functions in the model. As before, the dataset spans the period from 2000Q1 to 2012Q4, which coincides with the inflation targeting regime of the South African Reserve Bank (SARB). Table 1 contains a summary of the data series used, as well as their respective sources.

[11] See the Appendix for the model's entire set of log-linearised equations.

[12] Data for South African banks' interest income and loan book balances over the period January 2008 to December 2012 (January 2000 to December 2007) were taken from the South African Reserve Bank's BA120 (DI200) and BA100 (DI100) returns, respectively.

[13] Non-performing loans are calculated as the ratio of the banking sector's specific provisions in respect of loans and advances to its total loans and advances

Table 1: Observable variables

Variable	Series	Source
South Africa		
$\Delta\ln(\tilde{Y}_t)$	Real GDP	South African Reserve Bank
$\Delta\ln(\tilde{C}_t)$	Private consumption	
$\Delta\ln(\tilde{I}_t)$	Total fixed investment	
$\Delta\ln(\tilde{X}_t)$	Total exports	
$\Delta\ln(\tilde{M}_t)$	Total imports	
$\Delta\ln(\tilde{S}_t)$	Nominal effective exchange rate	
$\Delta\ln(\tilde{E}_t)$	Non-agricultural employment	
$\Delta\ln(\tilde{W}_t)$	Compensation of employees	
$\tilde{\pi}^i_t$	Fixed investment deflator	
$\tilde{R}_t$	Repo rate	
$\tilde{\zeta}_t$	Non-performing loans to total assets	
$\tilde{\pi}^c_t$	CPI inflation	StatsSA
$\tilde{\pi}^d_t$	PPI inflation, domestic manufacturing	
$\tilde{R}^b_t$	Effective lending rate	Author's own calculations
$\tilde{\bar{\pi}}^c_{t+1}$	Inflation target midpoint	
Foreign economy		
$\Delta\ln(\tilde{Y}^*_t)$	Real GDP (trade weighted)	GPM, CEPREMAP
$\tilde{\pi}^*_t$	CPI inflation (trade weighted)	
$\tilde{R}^*_t$	Policy interest rates (trade weighted)	

3.2 Measurement issues

The effective lending rate discussed above (the interest income received by banks divided by the value of their loan books), most likely exhibits some degree of noise that emanates from specific seasonal loan repayment patterns in the data.[14] As a result, the lending rate's measurement equation includes a measurement error η^b_t:

$$\tilde{R}^b_t = \ln(R^b) + \hat{R}^b_t + \eta^b_t \tag{28}$$

The standard deviation of the measurement error is calibrated such that 10 per cent of the variation in the lending rate accounts for these *exogenous* factors.[15]

3.3 Calibration

As before, the model is estimated with Bayesian techniques, while certain parameters are calibrated where necessary.

The parameters that correspond to the baseline DSGE model from Chapter **??** are calibrated to identical values, while fur parameters that govern the dynamics of savers and borrowers are also calibrated. Firstly, the share of savers p_s is set to 0.5, which implies that $p_b = 0.5$. The probability of a new type being drawn, $1-\chi$, is calibrated such that on average, a household could expect to remain of the same type for 10 years, after which there is a 50 per cent chance of changing its type. Accordingly, a household

[14]For example, during February the repayment of loans (and thus interest income) in the South African banking sector is generally lower than in other months of the year. This likely pertains to the fact that February not only follows the festive season, but also the start of the new school year, which often puts household balance sheets under pressure during this period.

[15]The full set of 17 measurement equations are reported in the Appendix.

Table 2: Calibrated parameters

β	Discount factor	0.9975	δ	Depreciation rate	0.025
A_L	Labour disutility constant	7.5	σ_L	Labour supply elasticity	5
ϕ_k	Capital adjustment cost	1150	α	Capital share in production	0.23
ϑ_c	Consumption imports share	0.36	ϑ_i	Investment imports share	0.48
θ_w	Calvo: wage setting	0.69	κ_w	Indexation: wage setting	0.5
λ_w	Wage setting markup	1.05	λ_d	Domestic price markup	1.1
η_c	Subst. elasticity: consumption	1.5	η_i	Subst. elasticity: investment	1.5
η_f	Subst. elasticity: foreign	1.25	ϕ_a	NFA/exchange rate elasticity	0.006
μ^z	Permanent technology growth	1.0085	π	Steady state inflation	1.0114
ρ_g	Govt. spending persistence	0.815	g_y	Govt. spending to GDP	0.197
π^*	Steady state foreign inflation	1.005			
Heterogeneous households					
p_s	Share of savers	0.5	χ	p(no type draw)	0.975
σ_s^{-1}	Cons. elasticity: savers	1.667	σ_b^{-1}	Cons. elasticity: borrowers	3.333
Financial intermediaries					
ω	Steady state gross spread	$1.025^{1/4}$	ζ	Steady state NPL	0.06
η_ζ	NPL elasticity	1.0	ρ_ζ	NPL persistence	0.7

discounts the expected path of the policy or lending rate – depending on whether it is of type s or type b – over the next ten years when making decisions at time t. Expectations beyond that point are essentially irrelevant. The intertemporal elasticities of substitution for consumption by borrowers and savers, σ_b^{-1} and σ_b^{-1}, are set to 3.333 and 1.667 respectively, such that the ratio $\sigma_s/\sigma_b = 2$. Cúrdia and Woodford (2010) calibrate this pairing to 13.8 and 2.76, such that $\sigma_s/\sigma_b = 5$. However, their relatively high calibration for these elasticities of substitution yields an excessive reaction of aggregate consumption in response to interest rate changes, which is largely at odds with the South African experience.

The remaining parameters pertain to the financial intermediary. As such, the steady state lending spread is calibrated to 250 basis points, such that the lending rate R_t^b equals 11.4 per cent in steady state – its sample average. The steady state of the non-performing loan ratio ζ_t is set to 6 per cent. This is higher than its sample average of 2 per cent, but ensures that the impact of non-performing loans on the lending spread matches its empirical relationship observed in the data, where a 1 percentage point increase in non-performing loans leads to an annualised lending spread increase of 50 basis points. The non-performing loan elasticity η_ζ is set to 1 such that in the log-linear solution of the model, increases of similar magnitudes in lending volumes and non-performing loans have an identical impact on the lending spread.

3.4 Priors

The financial intermediary extension of the model requires two additional parameters to be estimated, *i.e.* when compared to the set of parameter estimates from Chapter **??**: the elasticity of non-performing loans with respect to output θ_ζ, and the standard deviation of non-performing loan shocks σ_ζ. The elasticity of non-performing loans with respect to output in Table **??** is assumed to follow a fairly tight beta distribution around a mean of 0.408. The prior mean for this parameter is guided by Glen and Mondragón-Vélez's (2011) estimate of the contemporaneous impact of GDP growth on non-performing loans in a panel of 22 major developing economies, which includes South Africa. The standard deviation of the non-performing loans structural shock is assumed to follow an inverse-gamma distribution around a mean of 0.5, which is guided by the magnitude of the standard deviation of the non-performing loan series.

Apart from these two additional parameter estimates, the estimates for habit persistence and capital

Table 3: Priors and posterior estimation results

Parameter description		Prior			Posterior	
		Density[a]	Mean	Std. Dev.	Mean	90% interval
Consumption						
b_s	Habit formation by savers	B	0.867	0.05	0.930	[0.910 ; 0.948]
Investment						
ϕ_k	Capital adjustment cost	G	0.588	0.174	1.513	[1.121 ; 1.906]
Calvo parameters						
θ_d	Domestic prices	B	0.715	0.05	0.674	[0.596 ; 0.747]
θ_{mc}	Imported consumption prices	B	0.675	0.1	0.794	[0.679 ; 0.896]
θ_{mi}	Imported investment prices	B	0.675	0.1	0.831	[0.770 ; 0.888]
θ_x	Export prices	B	0.675	0.1	0.681	[0.596 ; 0.764]
θ_E	Employment	B	0.675	0.1	0.394	[0.305 ; 0.484]
Indexation						
κ_d	Domestic prices	B	0.5	0.15	0.510	[0.302 ; 0.739]
κ_{mc}	Imported consumption prices	B	0.5	0.15	0.327	[0.134 ; 0.498]
κ_{mi}	Imported investment prices	B	0.5	0.15	0.286	[0.114 ; 0.439]
Non-performing loans						
θ_ζ	NPL/output elasticity	G	0.408	0.025	0.367	[0.330 ; 0.401]
Taylor Rule						
ρ_R	Smoothing	B	0.8	0.05	0.858	[0.824 ; 0.889]
ϕ_π	Inflation	G	1.7	0.15	1.658	[1.451 ; 1.892]
$\phi_{\Delta\pi}$	Inflation (change)	G	0.3	0.1	0.265	[0.114 ; 0.399]
ϕ_y	Output gap	G	0.25	0.05	0.103	[0.072 ; 0.131]
$\phi_{\Delta y}$	Output gap (change)	G	0.125	0.05	0.176	[0.065 ; 0.288]
Persistence parameters						
ρ_{μ^z}	Permanent technology	B	0.75	0.1	0.738	[0.629 ; 0.847]
ρ_ε	Transitory technology	B	0.75	0.1	0.841	[0.772 ; 0.899]
ρ_i	Investment technology	B	0.75	0.1	0.865	[0.832 ; 0.899]
$\rho_{\tilde{z}^*}$	Asymmetric technology	B	0.75	0.1	0.755	[0.590 ; 0.915]
ρ_c	Consumption preference	B	0.75	0.1	0.842	[0.794 ; 0.893]
ρ_H	Labour supply	B	0.75	0.1	0.331	[0.210 ; 0.444]
ρ_a	Risk premium	B	0.75	0.1	0.881	[0.826 ; 0.935]
ρ_{λ^d}	Imported cons. price markup	B	0.75	0.1	0.571	[0.422 ; 0.717]
$\rho_{\lambda^{mc}}$	Imported cons. price markup	B	0.75	0.1	0.738	[0.531 ; 0.942]
$\rho_{\lambda^{mi}}$	Imported invest. price markup	B	0.75	0.1	0.742	[0.582 ; 0.892]
ρ_{λ^x}	Export price markup	B	0.75	0.1	0.455	[0.304 ; 0.606]
Structural shocks						
σ_ζ	Non-performing loans	IG	0.5	Inf	0.139	[0.103 ; 0.175]
σ_{μ^z}	Permanent technology	IG	0.4	Inf	0.243	[0.177 ; 0.303]
σ_ε	Transitory technology	IG	0.7	Inf	0.937	[0.647 ; 1.203]
σ_i	Investment technology	IG	0.4	Inf	1.419	[1.029 ; 1.761]
$\sigma_{\tilde{z}^*}$	Asymmetric technology	IG	0.4	Inf	0.226	[0.108 ; 0.335]
σ_c	Consumption preference	IG	0.4	Inf	0.835	[0.607 ; 1.068]
σ_H	Labour supply	IG	0.2	Inf	0.438	[0.333 ; 0.536]
σ_a	Risk premium	IG	0.5	Inf	0.945	[0.613 ; 1.273]
σ_d	Domestic price markup	IG	0.3	Inf	0.790	[0.587 ; 0.996]
σ_{mc}	Imported cons. price markup	IG	0.3	Inf	0.929	[0.638 ; 1.210]
σ_{mi}	Imported invest. price markup	IG	0.3	Inf	0.464	[0.215 ; 0.700]
σ_x	Export price markup	IG	0.3	Inf	1.348	[0.907 ; 1.764]
σ_R	Monetary policy	IG	0.15	Inf	0.218	[0.177 ; 0.262]

[a] B – Beta, G – Gamma, IG – Inverse Gamma, N – Normal, U – Uniform

adjustment costs also differ from their counterparts in Chapter **??**. Firstly, based on the assumption that savers and borrowers have different degrees of habit persistence, the degree of savers' habit persistence is estimated. Borrower habit persistence is calibrated to equal half of the savers' persistence, such that $b_s/b_b = 2$. While the prior for overall habit persistence in Chapter **??** followed a beta distribution around a mean of 0.65, the prior mean for saver habit persistence is adjusted by $(0.65r)/(1+\frac{1}{r}) = 0.867$, where $r = b_s/b_b$, such that the implied mean of "overall" habit persistence remains at 0.65. Secondly, the capital adjustment cost parameter is assumed to follow a gamma distribution around a mean of 0.588 with standard deviation 0.174. The prior for this parameter is based on the capital adjustment cost estimate by Christensen and Dib (2008) for a New Keynesian model that includes a financial accelerator mechanism.

The remaining parameters' prior means and densities are similar to Chapter **??**.

3.5 Posterior estimates

The posterior estimation results are summarised in Table 3, while Figure **??** in the Appendix contains the prior and posterior distributions. From the posterior results it can firstly be seen that the estimate of the elasticity of non-performing loans with respect to output at 0.367 is in-line with the estimate of Glen and Mondragón-Vélez (2011). The degree of habit formation by savers is estimated at 0.93, which implies that at the aggregate, habit formation by all households roughly equals 0.7, which is a fairly standard calibration of this parameter in the literature. The capital adjustment cost parameter's estimate of 1.513 is higher than the 0.588 estimate by Christensen and Dib (2008). Nevertheless, both estimates exceed the "reasonable" range of 0 to 0.5 suggested by Bernanke et al. (1999).

The Calvo parameter estimates indicate price contracts are generally reoptimised every 4 quarters, with the reoptimisation of domestic prices being most frequent and imported investment prices least frequent. The inflation indexation parameter for domestic prices is estimated to be around 0.5, which implies that an equal weight is placed on the current inflation target and past inflation during indexation. The degree of indexation for imported consumption and investment prices are both estimated to be around 0.3. As a result, a higher weight is placed on the current inflation target relative to past inflation during indexation.

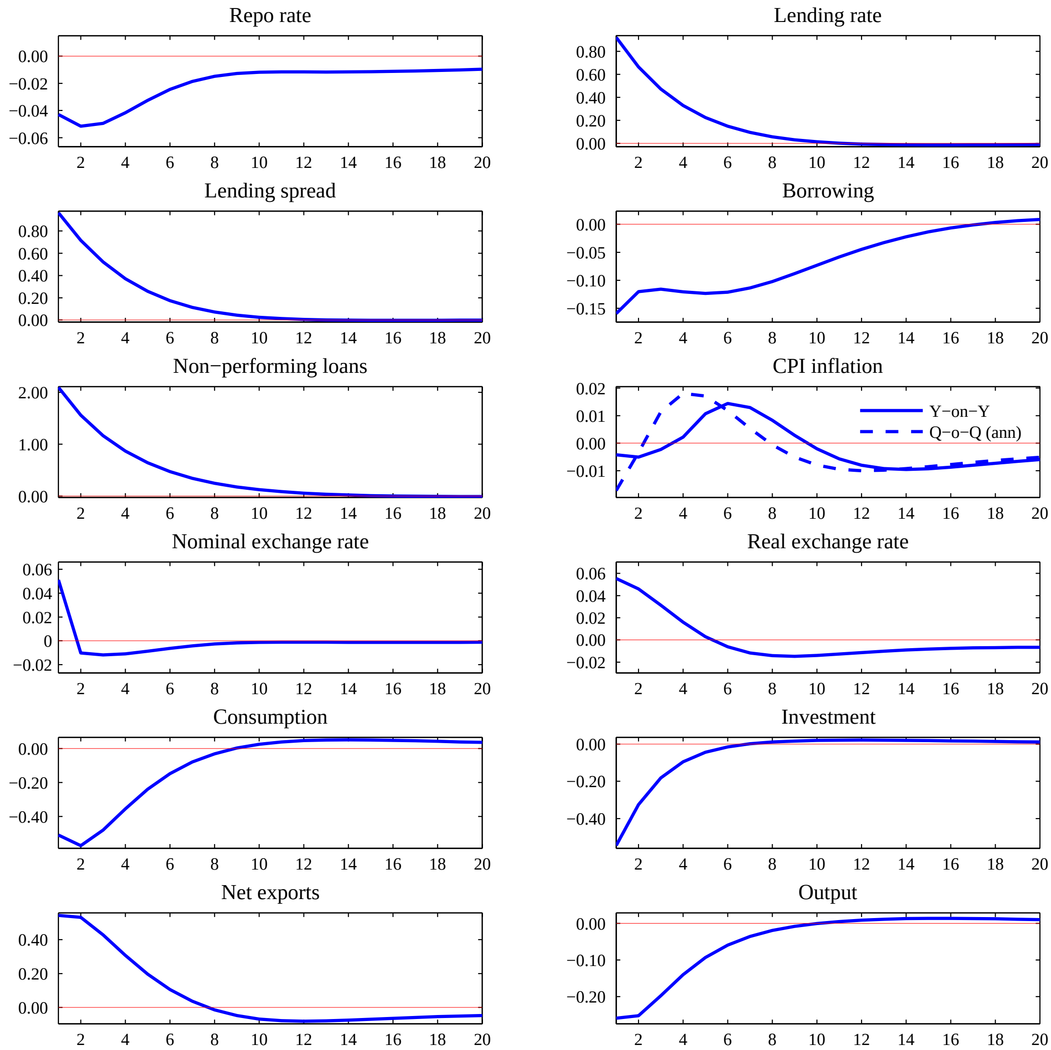
Turning to the estimates for Taylor rule parameters, the posterior mean of 0.858 for the degree of interest rate smoothing is slightly lower than Alpanda et al.'s (2010) estimate of 0.916. Nevertheless, it appears as if the SARB places a high weight on interest rate stabilisation. In addition, its reactions to inflation, the change in inflation and the level of the output gap are slightly lower than what was indicated by the prior. However, the policy reaction to a change in the output gap - a proxy for GDP growth – is slightly more pronounced.

Estimates for persistence of the shocks indicate that the exchange rate risk premium, investment technology and consumption shocks are most persistent, while labour supply shocks are least persistent. The standard deviations of the innovations to these shocks vary substantially. Consistent with the high weight placed on interest rate stabilisation, monetary policy shocks exhibit low volatility. In turn, export and investment shocks are the most volatile. Finally, the standard deviation of shocks to non-performing loans is lower than its prior and the least volatile of all the structural shocks.

4 Dynamics of a financial shock

The macroeconomic impact of a financial shock – represented by an increase in non-performing loans – is shown in Figure 2. The shock is calibrated to ensure that the lending spread increases by 1 percentage point as a result of an increase in non-performing loans. In turn it leads to a concomitant rise in the lending rate faced by borrowers. A higher lending rate slows down the real economy, as both consumption and investment decline by around half a per cent. The combined impact of higher lending rates, lower

Figure 2: Impulse response of a financial shock



consumption and lower investment reduces borrowing. The domestic slowdown does however improve net exports. Nevertheless, output ultimately declines by around 0.3 per cent. With the repo rate then responding to the real economic slowdown it is lowered slightly. Lowering the repo rate induces a nominal exchange rate depreciation, which counters the downward pressure on CPI inflation brought about by the slowing real economy. As a result, CPI inflation rises slightly in response to the financial shock, although in terms of magnitude it remains largely unchanged. It is important to highlight here that the impact of the exchange rate channel on inflation fundamentally distinguishes the results in this paper from those of Cúrdia and Woodford (2010), where in response to a non-performing loan shock, both output and inflation fall. However, in the open economy dimension, as can be seen here, the reaction of the exchange rate significantly alters the response of inflation.

5 Optimal response to financial shocks

In order to determine the optimal response of the central bank in the event of a financial shock, the Taylor rule in Equation 26 is adjusted such that the central bank also considers lending spreads with weight ϕ_ω when setting the policy rate:

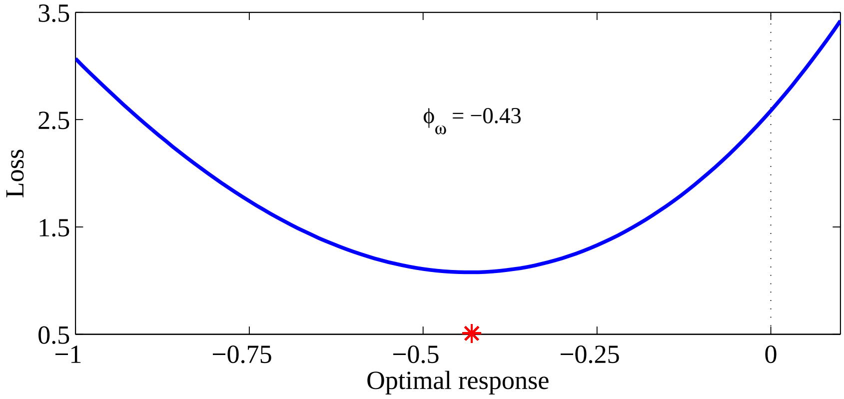
$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1-\rho_R)\left[\hat{\bar{\pi}}^c_t + \phi_\pi \left(\hat{\pi}^{c,4}_{t+1} - \hat{\bar{\pi}}^c_t\right) + \phi_{\Delta\pi}\hat{\pi}^c_t + \phi_y \hat{y}_t + \phi_{\Delta y}\Delta\hat{y}_t + \phi_\omega \hat{\omega}_t\right] + \varepsilon^R_t, \tag{29}$$

It is important to note here that optimal policy is not characterised by the typical Ramsey-type welfare-maximising competitive equilibrium.[16] Rather, the estimated Taylor rule without the lending spread is seen to represent the standard policy that has been followed by the South African Reserve Bank to date, and is therefore regarded as the benchmark against which to gauge alternative policy rules. Hence, it is assumed that the central bank aims to minimise the expected deviations of year-on-year CPI inflation and output when setting the policy rate, which can be represented by the following linear-quadratic loss function:

$$L = \sum_{t=1}^{\infty} \beta^t \left[(\hat{\pi}_t^{c,4})^2 + \lambda \hat{y}_t^2 \right], \tag{30}$$

where $\lambda = 0.5$. Accordingly, determining whether reacting to lending spreads in the event of a financial shock would be optimal, requires the comparison of the value of the loss function under the standard Taylor rule of Equation (26) to its value if Equation (29)'s rule above is followed. By varying the size of ϕ_ω in Equation (29), Figure 3 indicates that $\phi_\omega = -0.43$ minimises the central bank's loss function. This improves on the value of the loss function if $\phi_\omega = 0$. As such, it is optimal for the central bank to reduce

Figure 3: Optimal response to rising credit spreads that emanate from a financial shock



the repo rate by a further 0.43 basis points for every 100 basis point rise in the lending spread. This result compares favourably with Cúrdia and Woodford (2010), who find that the optimal $\phi_\omega = -0.66$, as opposed to McCulley and Toloui (2008) and Taylor (2008) who suggest a one-for-one reduction of the policy rate in reaction to rising credit spreads.

5.1 The role of the open-economy dimension

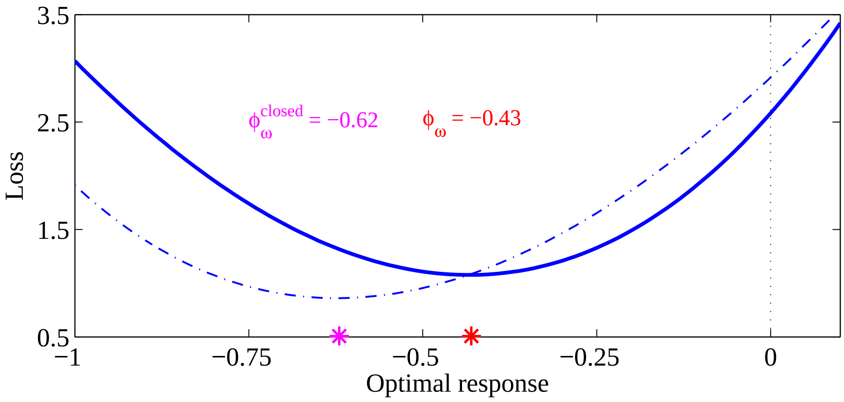
Moving aside the richer model structure, a key difference between this study and the stylised model of Cúrdia and Woodford (2010) lies in the inclusion of the open-economy dimension.[17] As such, in the open-economy setting, a reduction in the policy rate leads to a depreciation of the exchange rate, which adds an additional channel of inflationary pressure. In order to control for the impact of the open-economy dimension on the magnitude of the optimal response coefficient, all the open-economy channels in the model are closed down such that the model approximates a closed economy. Assuming that the central bank follows the same Taylor rule as before, the optimal response coefficient ϕ_ω^{closed} is

[16]Ramsey optimal policy is often derived in highly stylised and simple DSGE models. The large number of variables and frictions in this model would substantially complicate the calculation of such an optimal policy.

[17]Another key structural difference between this study and Cúrdia and Woodford (2010) is the inclusion of the adverse feedback loop – where the real economic slowdown leads to additional increases in non-performing loans. When closing down this channel, the absolute value of the optimal response coefficient declines with 0.02. This decrease in the parameter can be attributed to a less severe real economic slowdown in the absence of the adverse feedback loop, which in turn requires less policy accommodation.

then found to be -0.62, which is remarkably closer to Cúrdia and Woodford's (2010) closed-economy response coefficient of -0.66, as opposed to the -0.43 found in the open-economy setting (see Figure 4). Hence, it is the reaction of the exchange rate in response to accommodative monetary policy that creates an additional channel of inflation that is not present in a closed economy. As a result, an inflation-targeting central bank operating in a small open economy has limited scope to ease policy in the event of a financial shock, when compared to its closed economy counterpart.

Figure 4: Open-economy impact on optimal response coefficient



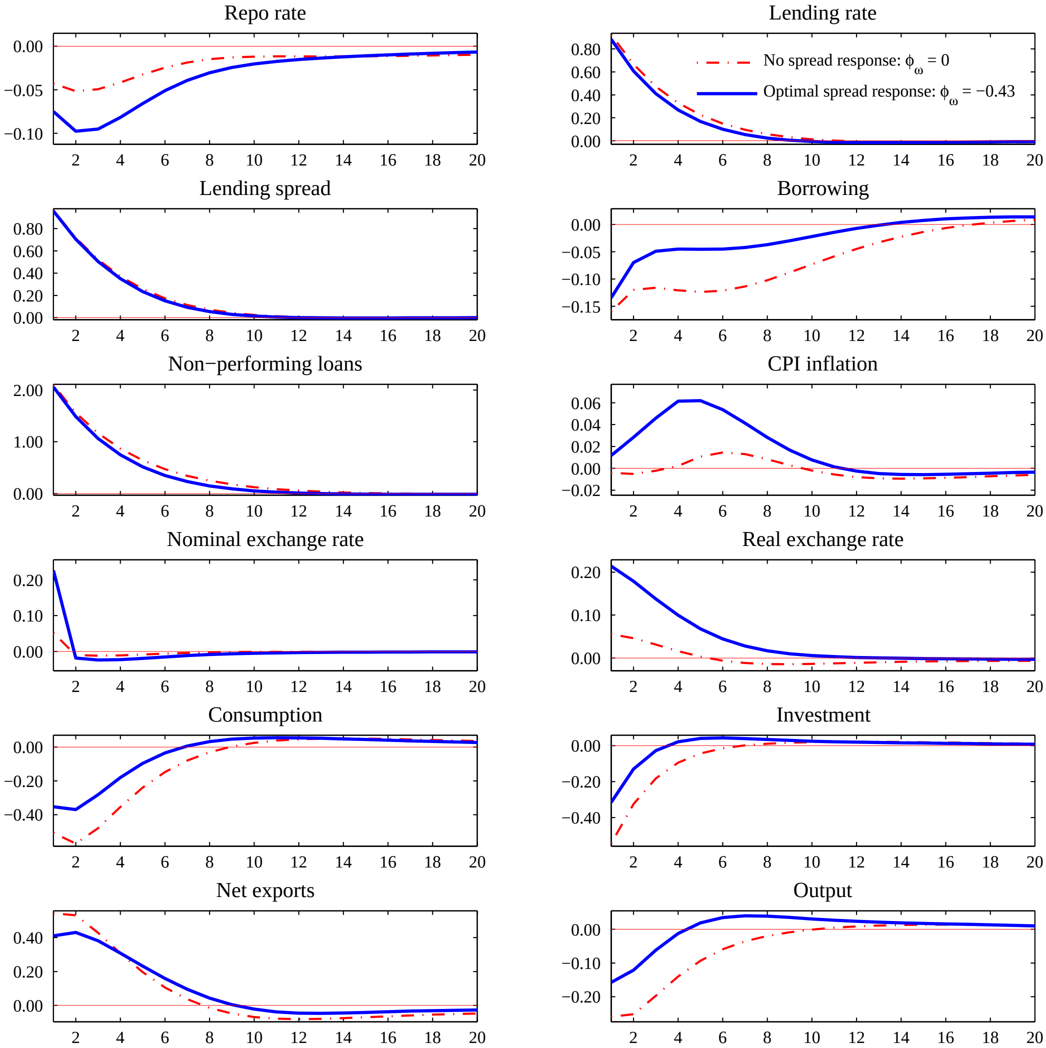
5.2 Dynamics of a financial shock under an optimal response

Having determined the magnitude of the ideal response to rising credit spreads in the event of a financial shock, Figure 5 compares the macroeconomic impact if the central bank were to follow the Taylor rule with $\phi_\omega = -0.43$, as opposed to the "no reaction" response where $\phi_\omega = 0$. Strikingly, the decline in output induced by the financial shock is almost halved by the central bank's reaction to the rising spread. The fall in consumption and investment is also substantially reduced, which in turn limits the decline in borrowing. However, inflation rises to a greater extent than before, largely as a result of the stronger depreciation of the nominal exchange rate. The improved real economic performance is beneficial to the level of non-performing loans of financial intermediaries, and although the effect is marginal, borrowers also enjoy lower lending rates.

6 Concluding remarks

Financial shocks, such as the one experienced during the recent global financial crisis, generally lead to higher credit spreads and lower real economic activity. In a bid to lessen the decline in real activity, central banks follow expansionary monetary policy by reducing their policy rates. However, their actions are countered by the higher credit spreads, such that the effective lending rate remains largely unchanged and monetary policy loses its efficacy. As a result, some have argued that the central bank reduce the policy rate on a one-for-one basis in response to the rising credit spreads induced by a financial shock (see McCulley and Toloui (2008) and Taylor (2008)), while Cúrdia and Woodford (2010) find that a less-than-unitary reaction coefficient is optimal. This paper contributes to the debate by analysing the optimal response of the central bank to rising credit spreads induced by a financial shock within the context of a small open economy. It does so by incorporating a banking sector, which lends at a spread above the policy rate, into the standard New Keynesian DSGE model developed in du Plessis et al. (2014). Moreover, within the model these spreads increase during times of financial distress. The optimal reaction coefficient that minimises the central bank's loss function is found to be less than one. However, when compared to the closed economy result of Cúrdia and Woodford (2010), the reaction co-

Figure 5: Impulse response of a financial shock when ϕ_ω = -0.43



efficient is slightly smaller – partly reflecting the additional inflation cost brought about by the exchange rate depreciation that is associated with a policy rate reduction.

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