The optimal monetary and macroprudential polices for the South African economy

Guangling Liu and Thabang Molise

ERSA working paper 811

February 2020

The optimal monetary and macroprudential policies for the South African economy

Guangling Liu[*] and Thabang Molise[†]

February 7, 2020

Abstract

We investigate the optimal design and effectiveness of monetary and macroprudential policies in promoting macroeconomic (price) and financial stability for the South African economy. We develop a New Keynesian dynamic stochastic general equilibrium model featuring a housing market, a banking sector and the role of macroprudential and monetary policies. Based on the parameter estimates from the estimation, we conduct an optimal rule analysis and an efficient policy frontier analysis, and compare the dynamics of the model under different policy regimes. We find that a policy regime that combines a standard monetary policy rule and a macroprudential policy rule delivers a more stable economic system with price and financial stability. A policy regime that combines an augmented monetary policy (policy rate reacts to financial conditions) with macroprudential policy is better at attenuating the effects of financial shocks, but at a much higher cost of price instability. Our findings suggest that monetary policy should focus solely on its primary objective of price stability and let macroprudential policy facilitate financial stability on its own.

Keywords: Monetary policy, Macroprudential policy, Financial stability, Capital requirement, Financial shock, DSGE model.

JEL classification: E32, E44, E52, E58 G28

---

[*]Corresponding author: Department of Economics, University of Stellenbosch, and South African Reserve Bank. E-mail address: davegliu@gmail.com

[†]Department of Economics, University of Stellenbosch, Stellenbosch, 7602, South Africa. Email address: molise42@gmail.com

1   Introduction

The main objective of macroprudential policy is to prevent the buildup of systemic risk in the financial markets. Since the 2007/08 financial crisis, most central banks around the world, including the South African Reserve Bank, have expanded their mandate by adding a financial stability objective to the macroeconomic (price) stability objective.[1] This presents a new challenge for central banks - how to achieve the optimal interaction between monetary and macroprudential policies. The difficulty is that the two policies mutually affect each other. While macroprudential policy provides a channel through which central banks promote financial stability, at the same time it affects macroeconomic conditions and the performance of other policies, especially monetary policy. For example, through its effect on credit growth, macroprudential policy affects monetary conditions and hence the conduct of monetary policy. Similarly, monetary policy can affect credit conditions through its interest rate channel.

The goals of monetary and macroprudential policies are mutually dependent. The literature has yet to find common ground on how central banks should coordinate monetary and macroprudential policies to facilitate a simultaneous pursuit of macroeconomic and financial stability. One strand of the literature examines the way a standard monetary policy that reacts to inflation and output interacts with macroprudential policy (e.g., Angelini et al., 2014; Quint and Rabanal, 2014; Rubio and Carrasco-Gallego, 2014, 2016). The general conclusion of these studies is that a combination of a standard monetary policy and macroprudential policy is effective in enhancing macroeconomic and financial stability, especially when the economy faces housing market and financial market shocks. Using a general equilibrium framework with endogenous credit risk, Tayler and Zilberman (2016) establish that a policy regime combining a strong anti-inflation monetary policy and an aggressive macroprudential policy that reacts to credit risk is effective in enhancing financial and macroeconomic stability when the economy is facing a technology (non-financial) shock. In a nutshell, these studies suggest that a policy regime in which monetary policy is exclusively assigned to the price stability objective while macroprudential policy is exclusively assigned to the financial stability objective facilitates a simultaneous pursuit of both macroeconomic and financial stability. This finding is consistent with studies that advocate a separation of responsibilities for monetary and macroprudential policies, such as Svensson (2012), Gelain et al. (2013), Suh (2014), Svensson (2017) and Turdaliev and Zhang (2019).

Another strand of the literature establishes an augmented monetary policy that reacts to financial variables, such as credit, interest rate spread and asset prices, in addition to inflation and output, and examines its interaction with macroprudential policy (e.g., Kannan et al., 2012; Angeloni and Faia, 2013; Agénor et al., 2013; Lambertini et al., 2013; Mendicino and Punzi, 2014; Bailliu et al., 2015). These studies suggest that a policy regime that combines an augmented monetary policy and macroprudential policy enhances macroeconomic and financial stability. Curdia and Woodford (2010), Gambacorta and Signoretti (2014), Verona et al. (2017) and Adrian and Liang (2018) argue that monetary policy should aim to achieve the broader objective of overall economic stability rather than the narrower one of price

---

[1] Jeanneau (2014) surveys 114 central bank laws and statutes and establishes that approximately 82% of central banks have an explicit financial stability objective. The South African Reserve Bank enacted the explicit mandate of maintaining and enhancing financial stability in 2017, through the Financial Sector Regulation Act 9 of 2017.

stability alone. In contrast, Benes and Kumhof (2015), Tayler and Zilberman (2016) and Turdaliev and Zhang (2019) show that a monetary policy rule that reacts to financial imbalances causes welfare to deteriorate, irrespective of whether it is implemented in conjunction with macroprudential policy and irrespective of what kind of shock is hitting the economy.

This paper is the first of its kind to investigate the interaction between monetary and macroprudential policies in South Africa. Most of the literature examines the interaction between monetary and macroprudential policies in developed economies and little research has been done on emerging market economies like South Africa.[2] One of the few studies that examine the interaction between monetary and macroprudential policies in the context of developing economies is Agénor et al. (2013). In South Africa, bank lending is more or less equally distributed between households and corporates. The South African credit market data show that over the period 2000Q1–2016Q4 the average ratio of household loans to total bank loans was 52% while that of corporate loans to total bank loans was 48%. In addition, the two types of credit behaved differently in the past.[3] Therefore, a framework with heterogeneous borrowers allows us to examine the impact of a broader range of financial shocks emanating from different sectors of the credit market and the stabilisation effect of monetary and macroprudential policies in South Africa. This comprises the second contribution of the paper.

The paper also contributes to the literature by examining the optimal interaction between monetary and macroprudential policies in a framework where heterogeneous borrowers (households and non-financial corporates) from distinct sectors of the credit market co-exist. Most of the literature focuses on the interaction between the two policies in a framework where there is only one type of borrower: either household or non-financial corporate. We argue that policy analysis based on this kind of framework is likely to miss some of the key transmission channels and the trade-off between macroeconomic and financial stability in the economy, and is therefore less informative for policymakers. Angelini et al. (2014) is one of the few studies which examine the interaction between monetary and macroprudential policies in a framework where household and non-financial corporate borrowers co-exist. In contrast to Angelini et al. (2014), we also consider a monetary policy rule that reacts to credit growth and study its interaction with macroprudential policy. Furthermore, our analysis considers three types of financial shock: housing demand, loan-to-value (LTV) and non-performing loan (NPL) shock.

The main objective of the paper is to determine the optimal design of a simultaneous deployment of monetary and macroprudential policies and investigate its effectiveness in enhancing macroeconomic and financial stability. We measure macroeconomic stability in terms of the volatility of inflation, and financial stability in terms of the volatility of credit-to-output ratio and house prices, in line with Rubio and Carrasco-Gallego (2014) and Agénor and Pereira da Silva (2017). We consider two alternative policy regimes, in which monetary and macroprudential policies are jointly implemented, and compare their effectiveness against a benchmark regime in which there is only monetary policy. The macroprudential

---

[2]A non-exhaustive list is Kannan et al. (2012), Angeloni and Faia (2013), Lambertini et al. (2013), Angelini et al. (2014), Rubio and Carrasco-Gallego (2014), Quint and Rabanal (2014), Mendicino and Punzi (2014), Bailliu et al. (2015), Benes and Kumhof (2015), Rubio and Carrasco-Gallego (2016), Tayler and Zilberman (2016), Gelain and Ilbas (2017) and Turdaliev and Zhang (2019).

[3]See Liu and Molise (2019) for a detailed discussion.

policy considered in this study is a countercyclical capital requirement (CcCR) rule that relates the bank capital requirement ratio to deviations of the credit-to-output ratio from its steady state, which is in line with Basel III countercyclical capital buffers. In the benchmark regime (regime I), monetary policy follows a standard Taylor-type interest rate rule that relates the policy rate to inflation and output growth. There is no macroprudential rule in regime I, and the capital requirement ratio is constant. The first alternative policy regime (regime II) is a combination of a standard Taylor rule and the CcCR rule. The second alternative policy regime (regime III) is a combination of an augmented Taylor rule and the CcCR rule. The augmented Taylor rule relates the policy rate to credit growth in addition to inflation and output growth. Under regime III, we also investigate whether monetary policy should promote financial stability in addition to its primary objective of price stability.

To conduct our analysis, we develop a New Keynesian dynamic stochastic general equilibrium (DSGE) model with financial frictions, a housing market, a stylised banking sector and the role of monetary and macroprudential policies. Specifically, we add price stickiness to Iacoviello (2015) model, which allows us to study the price stabilising effect of the monetary policy. Second, in line with Bouvatier and Lepetit (2012), we introduce endogenous loan losses in the model by assuming borrowers do not repay a proportion of loans borrowed from the previous period. This is in contrast to Iacoviello (2015), in which the author assumes that loan losses are exogenous. Lastly, we incorporate the role of macroprudential policy into the model.

We first estimate the model using Bayesian techniques with South African data over the sample period 2000Q1–2016Q4. Based on the estimated results (parameter values), we then derive the optimal combination of monetary and macroprudential policy rules assuming the central bank minimises a policy loss function. The loss function is in terms of a weighted sum of the volatility of inflation, output, credit-to-output ratio and house prices.[4] We find that, to achieve financial and macroeconomic stability objectives, the optimal monetary policy rule requires a smaller response to inflation and a bigger response to output than the estimated responses under the benchmark regime. The optimal macroprudential policy rule requires the central bank to adjust the capital requirement ratio proportionately to deviations of the credit-to-output ratio from the steady state, irrespective of whether it is jointly deployed with a standard monetary policy rule or an augmented monetary policy rule. Regime III delivers the highest welfare gains, but at a much higher cost of increasing inflation volatility.

Based on the optimal policy rules derived previously, we then compare the dynamics of the model under the three policy regimes, following housing demand, LTV and NPL shocks. We find that a simultaneous deployment of the optimal monetary and macroprudential policy rules attenuates fluctuations in the housing market, the credit market and the real sector. A policy regime that combines a standard monetary policy rule and macroprudential policy rule (regime II) delivers a more stable economic system than a regime that combines an augmented monetary policy rule and macroprudential policy rule

---

[4]We assume that monetary and macroeconomic policies are conducted under full coordination, i.e., the two policies are used to minimise the same objective function. We leave aside a case where there are two policymakers each assigned a separate mandate: a central bank assigned a macroeconomic stability mandate and a macroprudential authority assigned a financial stability mandate. We do not attempt to study the interaction between monetary and macroprudential policies in a non-cooperative setting. This is beyond the scope of this paper and therefore left for future research.

(regime III). The central bank faces a more severe trade-off between price and financial stability when monetary policy also responds to credit growth. While this policy regime seems to be effective from the financial stability point of view, it can compromise price stability (Tayler and Zilberman, 2016). This is especially the case when shocks generate a negative correlation between credit and inflation. As we note in our analysis, a housing demand, LTV or NPL shock generates a negative correlation between credit and inflation. The central bank is forced to choose between price stability or financial stability when deploying an augmented monetary policy rule. The policy rate response required to achieve price stability is inconsistent with that required to achieve financial stability. For example, a positive housing demand shock increases credit but reduces inflation. The reduction in inflation calls for a reduction in the policy rate, but a boom in the credit market calls for an increase in the policy rate. This conflict compromises the central bank's ability to deliver on it's price stability mandate. Nevertheless, the trade-off between price and financial stability is minimised and the policy conflict is absent under regime II.

Lastly, we perform a policy frontier analysis to assess the efficiency of a simultaneous deployment of monetary and macroprudential policies under the three policy regimes. We see that the introduction of macroprudential policy enhances both financial and price stability. A comparison between regime II and regime III suggests that regime II is more efficient than regime III in promoting financial and price stability. The efficient policy frontiers under the three policy regimes present a clear trade-off between inflation and credit-to-output ratio volatilities, as the central bank adjusts its preference for stabilising the credit-to-output ratio relative to stabilising inflation. The maximum attainable reduction in credit-to-output volatility can be achieved at the expense of increasing inflation volatility. The relatively inelastic efficient policy frontiers, especially when the economy faces a housing demand shock, imply that it is not wise for the central bank to put a relatively high weight on the credit-to-output ratio in its loss function. This is because a marginal reduction in the volatility of the credit-to-output ratio is achieved at a relatively high cost in terms of the volatility of inflation.

The rest of the paper is organised as follows. Section 2 describes the model and Section 3 discusses the model estimation strategy and presents the estimation results. Section 4 describes the model's business cycle properties. Section 5 studies the optimal combination of monetary and macroprudential policies under the two alternative policy regimes and compares their effectiveness in enhancing financial and macroeconomic stability. Section 6 reports the results of the impulse response analysis and Section 7 the results of the efficient policy frontier analysis. Section 8 concludes.

2 The model

We construct a closed economy New Keynesian DSGE model.[5] The model economy is populated by two types of households (patient and impatient), entrepreneurs, retailers, banks and a central bank. The two types of households work and consume final consumption goods and housing services. In equilibrium, patient households are savers while impatient households are borrowers. Entrepreneurs produce intermediate goods using labour and housing (commercial real estate) as inputs.[6] They also consume final consumption goods and borrow from banks. The two types of borrowers (impatient households and entrepreneurs) face a borrowing constraint which ties the amount of borrowing to the expected value of collateral assets (housing stock). Retailers are the source of nominal rigidity in the model. They buy intermediate goods from entrepreneurs and transform them into final consumption goods. Banks mediate funds between savers and borrowers. Banks are subject to the capital requirement constraint. While the constraint limits banks' ability to provide loans to borrowers, it also constrains the amount of deposits they can take from savers. The central bank implements monetary and macroprudential policies to safeguard macroeconomic and financial stability.

2.1 Patient Households (Savers)

The representative patient household maximises the expected discounted lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta_s^t \left[(1-\eta_s) log(C_{s,t} - \eta_s C_{s,t-1}) + jA_{j,t} log(H_{s,t}) + \tau log(1 - N_{s,t}) \right],$$
(1)

where E_0 is the expectation operator and $\beta_s \in (0,1)$ is the household's subjective discount factor. $C_{s,t}$ is consumption, $H_{s,t}$ is housing stock and $N_{s,t}$ is supply of labour (hours of work).[7] j and τ are weights of housing and leisure $(1 - N_{s,t})$ in the utility function, respectively. $A_{j,t}$ is the housing demand shock that evolves according to the following law of motion:

$$log A_{j,t} = \rho_j log A_{j,t-1} + \xi_{j,t},$$
(2)

where ρ_j is a parameter representing the persistence of the shock. $\xi_{j,t} \sim i.i.d.N(0,\sigma_j^2)$ is the white noise process, normally distributed with mean zero and variance σ_j^2.

In each period, the household accumulates housing stock, $H_{s,t}$, makes deposits, D_t, at the bank and supplies labour to entrepreneurs and earns real wage rate $w_{s,t} \equiv W_{s,t}/P_t$, where $W_{s,t}$ is nominal wage

---

[5]We opt for a closed economy model for the following reasons. First, the purpose of this study is to investigate the optimal design and the effectiveness of a simultaneous deployment of monetary and macroprudential policies, not the impacts of external shocks on the domestic economy. Second, activities of the South African credit market are largely confined to the domestic economy. Last, the banking sector has a relatively low exposure to foreign currency. The average ratio of foreign currency deposits to total liabilities is approximately 4.6% while the ratio of foreign currency loans to total assets is approximately 5.0% over the period 2008Q1–2016Q4 (SARB, 2018).

[6]Entrepreneurs represent non-financial corporates or firms.

[7]In the utility function, $H_{s,t}$ represent consumption of housing services which is proportional to housing stock. Consumption appears in the utility function relative to external habit formation, with η_s measuring degree of habit persistence. In line with Iacoviello (2015) and Guerrieri and Iacoviello (2017), the scaling factor $1 - \eta_s$ ensures that the marginal utility of consumption is independent of habit parameter in steady state.

rate and P_t is aggregate price level. The household also receives lump-sum transfers in the form of profits, $F_{s,t}$, from the retailers. The patient household owns retail firms. The household's budget constraint is given by:

$$C_{s,t} + D_t + q_t(H_{s,t} - H_{s,t-1}) = w_{s,t}N_{s,t} + \frac{R_{t-1}}{\pi_t}D_{t-1} + F_{s,t}, \tag{3}$$

where $q_t \equiv Q_t/P_t$ is real house prices and Q_t is nominal house prices. $\pi_t = P_t/P_{t-1}$ is gross inflation rate. R_{t-1}/π_t is the real gross return a on one-period risk-free deposit, where R_t is the nominal deposit rate, which is equal to the policy rate set by the central bank. $F_{s,t} = \frac{X_t-1}{X_t}Y_t$, where X_t is the markup charged by the retail firms and Y_t is output.

Let $U_{Cs,t} = \frac{1-\eta_s}{C_{s,t} - \eta_s C_{s,t-1}}$ be the marginal utility of consumption. The first order conditions which define the household's problem are as follows:

$$1 = \beta_s E_t\left(\frac{U_{Cs,t+1}}{U_{Cs,t}}\frac{R_t}{\pi_{t+1}}\right), \tag{4}$$

$$q_t = j\frac{A_{j,t}}{H_{s,t}U_{Cs,t}} + \beta_s E_t\left(\frac{U_{Cs,t+1}}{U_{Cs,t}}q_{t+1}\right), \tag{5}$$

$$w_{s,t} = \frac{\tau}{(1-N_{s,t})U_{Cs,t}}. \tag{6}$$

Eq. (4) is the standard Euler equation for consumption, which describes the consumption-saving decision. Eq. (5) is the asset pricing equation for housing, which equates the marginal cost of housing to its marginal benefit. Eq. (5) can also be interpreted as the patient household's demand for housing. Eq. (6) is the household's labour supply condition. It equates the real wage rate to the marginal rate of substitution between consumption and leisure.

2.2 Impatient Households (Borrowers)

Like the patient household, the representative impatient household maximises the expected discounted lifetime utility:

$$E_0\sum_{t=0}^{\infty}\beta_b^t\left[(1-\eta_b)log(C_{b,t} - \eta_b C_{b,t-1}) + jA_{j,t}log(H_{b,t}) + \tau log(1-N_{b,t})\right], \tag{7}$$

where β_b is the impatient household's subjective discount factor such that $\beta_b < \beta_s$. $C_{b,t}$ is consumption, $H_{b,t}$ is housing stock and $N_{b,t}$ is labour supply. The household's budget constraint is given by:

$$C_{b,t} + \frac{R_{b,t-1}}{\pi_t}(1 - \zeta_{b,t}(1-\vartheta_b))L_{b,t-1} + q_t(H_{b,t} - H_{b,t-1}) = w_{b,t}N_{b,t} + L_{b,t}, \tag{8}$$

where $L_{b,t}$ is bank loans to the household, which accrue a real gross interest rate of $R_{b,t-1}/\pi_t$. $w_{b,t}$ is the real wage rate for the household. $\zeta_{b,t}$ is a fraction of household NPLs which captures partial defaults by the household on loan contract. Following Iacoviello (2015) and Zhang (2019), we introduce $\zeta_{b,t}$ in line with the literature on the wealth re-distribution (transfer) effect. For the household, an increase in the fraction of NPLs represents an indirect increase in wealth (income gain). This is because by paying less than the agreed amount on the loan contract, the household is able to spend more than previously

anticipated. For the bank (the lender), the increase in the fraction of NPLs increases the losses on the bank's loan portfolio and thus reduces the bank's wealth (income). The same variable appears in the bank's budget constraint, but with a negative sign (or on the expenditure side of the budget constraint). Following Bouvatier and Lepetit (2012), we assume that $\zeta_{b,t}$ is endogenous and depends on general economic conditions (output growth).[8] We argue that NPLs (loan defaults) are symptoms (manifestations) of distress elsewhere in the economy, such as deteriorating economic conditions that reduce borrowers' ability to repay loans. This modification also allows us to mimic a real world setting and introduces an additional macro-financial feedback loop into the model, in which deteriorating macroeconomic and financial conditions become mutually reinforcing. Specifically, the fraction of household NPLs evolves as follows:

$$\zeta_{b,t} = \zeta_b(\zeta_{b,t-1})^{\rho_{\varepsilon b}}(Y_t/Y_{t-1})^{-\chi_\zeta}e^{\xi_{\varepsilon b,t}}, \tag{9}$$

where ζ_b is the steady-state value of household NPLs and $\chi_{\zeta b} > 0$ measures the elasticity of the NPLs with respect to output growth. $\rho_{\varepsilon b}$ measures the persistence of the NPLs. $\xi_{\varepsilon b,t}$ is an independent and identically distributed (i.i.d.) NPL shock with mean zero and variance $\sigma_{\varepsilon b}^2$. That is, $\xi_{\varepsilon b,t} \sim i.i.d.N(0,\sigma_{\varepsilon b}^2)$. Following Zhang (2019), we assume that in the event of a default the household incurs an indirect cost in the form of a bad repayment record that results in a low credit score. To capture the cost associated with credit default, we introduce $\vartheta_b \in [0,1]$, which is a fraction of the wealth transfer that the household must use to pay for the cost associated with the credit default.

The household also faces the following borrowing constraint that limits the amount of borrowing to a fraction m_b of the expected value of housing:[9].

$$L_{b,t} \leq m_b E_t\left(\frac{q_{t+1}}{R_{b,t}}H_{b,t}\pi_{t+1}\right)\gamma_{b,t}. \tag{10}$$

$m_b \in (0,1)$ is the LTV ratio for the impatient household. The term $\gamma_{b,t}$ is an exogenous shock to the borrowing capacity of the household in line with Mendicino and Punzi (2014) and Iacoviello (2015). This shock evolves as follows:

$$log\gamma_{b,t} = \rho_{\gamma b}log\gamma_{b,t-1} + \xi_{\gamma b,t}, \tag{11}$$

where $\rho_{\gamma b}$ is a parameter governing the persistence of the shock. $\xi_{\gamma b,t} \sim i.i.d.N(0,\sigma_{\gamma b}^2)$ is the white noise process, normally distributed with mean zero and variance $\sigma_{\gamma b}^2$. The shock captures exogenous changes in the bank's (lender's) confidence or optimism in the credit market which changes the bank's valuation of the collateral assets (housing).[10]

Let $U_{Cb,t} = \frac{1-\eta_b}{C_{b,t}-\eta_b C_{b,t-1}}$ be the marginal utility of consumption and $\lambda_{b,t}$ be the multiplier on the borrowing constraint. The first order conditions which define the impatient household's problem are as follows:

$$1 - \frac{\lambda_{b,t}}{U_{Cb,t}} = \beta_b E_t\left(\frac{U_{Cb,t+1}}{U_{Cb,t}}\frac{R_{b,t}\left(1-\zeta_{b,t+1}(1-\vartheta_b)\right)}{\pi_{t+1}}\right), \tag{12}$$

---

[8]This is in contrast to Iacoviello (2015), in which the author introduces a redistribution shock (that transfers wealth from the bank to the borrowers, analogous to a fraction of NPLs) in an ad hoc manner and assumes that it is exogenous.

[9]The assumption that $\beta_b < \beta_s$ ensures that the borrowing constraint binds in the neighborhood of the steady state. As is common in the literature, we also assume that the magnitude of uncertainty in the economy (the size of the shocks) is too small to induce agents to borrow less than the credit limit (see for e.g., Iacoviello, 2005).

[10]See also Ngo (2015) and Funke et al. (2018).

$$q_t = j\frac{A_{j,t}}{H_{b,t}U_{Cb,t}} + \beta_b E_t\left(\frac{U_{Cb,t+1}}{U_{Cb,t}}q_{t+1}\right) + m_b E_t\left(\frac{\lambda_{b,t}}{U_{Cb,t}}\frac{\pi_{t+1}}{R_{b,t}}q_{t+1}\right)\gamma_{b,t}, \tag{13}$$

$$w_{b,t} = \frac{\tau}{(1-N_{b,t})U_{Cb,t}}. \tag{14}$$

Eq. (12) describes the household's demand for bank loans. Eq. (13) is the household's optimal demand for housing. It equates the current price of housing to its marginal benefit, which is given by the marginal utility of consuming one extra unit of housing, its expected resale value and its ability to serve as collateral. Eq. (14) is the labour supply condition for the household.

2.3 Entrepreneurs

The representative entrepreneur maximises the expected discounted lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta_e^t (1-\eta_e)log(C_{e,t} - \eta_e C_{e,t-1}), \tag{15}$$

where β_e is the entrepreneur's subjective discount factor such that $\beta_e < \beta_s$. $C_{e,t}$ is the entrepreneur's consumption. Since the entrepreneur is the owner of production firms, $C_{e,t}$ can be regarded as profits or dividends. Therefore, $\eta_e C_{e,t-1}$ captures some form of dividend smoothing in line with Liu et al. (2013). Liu et al. (2013) point out that this form of dividend smoothing is essential for the model to adequately explain the dynamics between asset prices and real variables.

In each period, the representative entrepreneur, z, produces intermediate goods, $Y_t(z)$, using the patient and impatient households' labour supply, $N_{s,t}(z)$ and $N_{b,t}(z)$, and housing, $H_{e,t}(z)$, as inputs. The entrepreneur then sells these goods to the retailers at a wholesale price $P_{w,t}(z)$. Production technology is given by a constant return to scale Cobb-Douglas production function:

$$Y_t(z) = Z_t H_{e,t-1}(z)^{\nu}[N_{s,t}(z)^{1-\sigma}N_{b,t}(z)^{\sigma}]^{1-\nu}, \tag{16}$$

where $\nu \in (0,1)$ is the elasticity of output with respect to housing and, $\sigma \in (0,1)$ is the relative share of the impatient household's labour supply in the production (share of the impatient household's labour income). The technology shock, Z_t, evolves according to the following law of motion:

$$log(Z_t) = \rho_z log(Z_{t-1}) + \xi_{z,t}, \tag{17}$$

where ρ_z is the persistence of the shock. $\xi_{z,t} \sim i.i.d.N(0,\sigma_z^2)$ is the white noise process, normally distributed with mean zero and variance σ_z^2.

The entrepreneur's budget constraint is given by:[11]

$$C_{e,t} + q_t(H_{e,t} - H_{e,t-1}) + \frac{R_{e,t}}{\pi_t}(1 - \zeta_{e,t}(1-\vartheta_e))L_{e,t-1} + w_{s,t}N_{s,t} + w_{b,t}N_{b,t} = \frac{1}{X_t}Y_t + L_{e,t}, \tag{18}$$

where $X_t = P_t/P_{w,t}$ is the markup or the inverse of the marginal cost. $L_{e,t}$ is bank loans to the entrepreneur, which accrue a real gross interest rate, $R_{e,t}/\pi_t$. $\zeta_{e,t}$ is a fraction of entrepreneur NPLs, which captures partial defaults by the entrepreneur on the loan contract, as in the case of the impatient

---

[11] Note that symmetry across entrepreneurs allows us to write the budget constraint without the index z.

household. ϑ_e is a fraction of the wealth transfer that the entrepreneur must pay for the costs related to the default, similar to that of the impatient household. The fraction of entrepreneur NPLs evolves as follows:

$$\zeta_{e,t} = \zeta_e(\zeta_{e,t-1})^{\rho_{\varepsilon e}}(Y_t/Y_{t-1})^{-\chi_{\zeta e}}e^{\xi_{\varepsilon e,t}}, \tag{19}$$

where ζ_e is the steady-state value of entrepreneur NPLs and $\chi_{\zeta e} > 0$ measures the elasticity of the NPLs with respect to output growth. $\rho_{\varepsilon e}$ measures the persistence of the NPLs. $\xi_{\varepsilon e,t}$ is an independent and identically distributed (i.i.d.) NPL shock with mean zero and variance $\sigma_{\varepsilon e}^2$. That is, $\xi_{\varepsilon e,t} \sim i.i.d.N(0, \sigma_{\varepsilon e}^2)$.

The entrepreneur also faces a borrowing constraint, which limits the total amount of borrowing to the expected value of housing. That is:

$$L_{e,t} \leq m_e E_t\left(\frac{q_{t+1}}{R_{e,t+1}}H_{e,t}\pi_{t+1}\right)\gamma_{e,t}, \tag{20}$$

where $m_{e,t}$ is the LTV ratio for the entrepreneur. The term $\gamma_{e,t}$ is an exogenous shock to the borrowing capacity of the entrepreneur which evolves as follows:

$$log\gamma_{e,t} = \rho_{\gamma e}log\gamma_{e,t-1} + \xi_{\gamma e,t}, \tag{21}$$

where $\rho_{\gamma e}$ is the persistence of the shock. $\xi_{\gamma e,t} \sim i.i.d.N(0, \sigma_{\gamma e}^2)$ is the white noise process, normally distributed with mean zero and variance $\sigma_{\gamma e}^2$.

Let $U_{Ce,t} = \frac{1-\eta_e}{C_{e,t}-\eta_e C_{e,t-1}}$ be the marginal utility of consumption and $\lambda_{e,t}$ be the multiplier on the borrowing constraint (20). The first order conditions which define the entrepreneur's problem are as follows:

$$1 - \frac{\lambda_{e,t}}{U_{Ce,t}} = \beta_e E_t\left(\frac{U_{Ce,t+1}}{U_{Ce,t}}\frac{R_{e,t+1}\left(1 - \zeta_{e,t+1}(1-\vartheta_e)\right)}{\pi_{t+1}}\right), \tag{22}$$

$$q_t = \beta_e E_t\left[\frac{U_{Ce,t+1}}{U_{Ce,t}}\left(\frac{\nu}{X_{t+1}}\frac{Y_{t+1}}{H_{e,t}} + q_{t+1}\right)\right] + m_e E_t\left(\frac{\lambda_{e,t}}{U_{Ce,t}}\frac{\pi_{t+1}}{R_{e,t+1}}q_{t+1}\right)\gamma_{e,t}, \tag{23}$$

$$w_{s,t} = (1-\sigma)(1-\nu)\frac{1}{X_t}\frac{Y_t}{N_{s,t}}, \tag{24}$$

$$w_{b,t} = \sigma(1-\nu)\frac{1}{X_t}\frac{Y_t}{N_{b,t}}. \tag{25}$$

Eq. (22) is the optimal demand for bank loans. Eq. (23) represents the entrepreneur's demand for housing. It equates the current price of housing to its expected resale value plus the pay-off from holding this asset for one period (given by its marginal productivity and its ability to serve as collateral asset). Eqs. (24) and (25) are the optimal demand for patient and impatient households' labour, respectively.

2.4 Retailers

There is a continuum of monopolistically competitive retailers, indexed by $k \in [0,1]$. They buy undifferentiated intermediate goods, $Y_t(z)$, from entrepreneurs at the price, $P_{w,t}$. They then brand these goods and transform them into differentiated goods, $Y_t(k)$, at no costs and sell them at the price, $P_t(k)$. The final good, Y_t, is a constant elasticity of substitution (CES) composite of the continuum of differentiated goods:

$$Y_t = \left[\int_0^1 Y_t(k)^{(\epsilon-1)/\epsilon}dk\right]^{\epsilon/(\epsilon-1)}, \tag{26}$$

where $\epsilon > 1$ is the intratemporal elasticity of substitution across goods. The profit maximisation yields the demand for good k as:[12]

$$Y_t(k) = \left(\frac{P_t(k)}{P_t}\right)^{-\epsilon} Y_t. \tag{27}$$

The price index is then given by:

$$P_t = \left[\int_0^1 P_t(k)^{1-\epsilon} dk\right]^{1/(\epsilon-1)}. \tag{28}$$

To motivate for price rigidity, following Calvo (1983), we assume that the retailers operate in a monopolistically competitive environment and set prices in a staggered manner. In each period, each retailer gets the opportunity to adjust prices to a new level with a probability of $(1-\theta)$. Furthermore, we introduce price inertia by assuming that prices of the retailers who do not receive the Calvo signal are partially indexed to the last period's inflation rate as in Smets and Wouters (2003). Let $\tilde{P}_t(k)$ be the reset price and the corresponding demand be $\tilde{Y}_{t+i}(k) = \left(\tilde{P}_t(k)/P_{t+i}\right)^{-\epsilon} Y_{t+i}$. Then, the optimal reset price solves:

$$\sum_{i=0}^{\infty} \theta^i \left[\Lambda_{t,i}\left(\frac{\tilde{P}_t(k)}{P_{t+i}} - \frac{X}{X_{t+i}}\right)\tilde{Y}_{t+i}(k)\right] = 0, \tag{29}$$

where, $\Lambda_{t,i} = \beta^i (U_{Cs,t+i}/U_{Cs,t})$ is the patient household's stochastic discount factor and X_t is the markup, which at the steady state is $X = \epsilon/(\epsilon - 1)$.

The aggregate price level is given by:

$$(P_t)^{1/(1-\epsilon)} = \theta\left[P_{t-1}\left(\frac{P_{t-1}}{P_{t-2}}\right)^{\iota_p}\right]^{1-\epsilon} + (1-\theta)(\tilde{P}_t)^{1-\epsilon}, \tag{30}$$

where ι_p is the degree of indexation to past inflation. Combining Eq. (29) and Eq. (30) and log-linearising yields a forward-looking New Keynesian Phillips curve to which we add a normally distributed cost-push shock as follows:

$$\hat{\pi}_t = \frac{\iota_p}{1+\iota_p\beta_s}\hat{\pi}_{t-1} + \frac{\beta_s}{1+\iota_p\beta_s}E_t\hat{\pi}_{t+1} - \frac{(1-\theta)(1-\beta_s\theta)}{(1+\iota_p\beta_s)\theta}\hat{x}_t + \xi_{\pi,t}, \tag{31}$$

where $\xi_{\pi,t}$ is an independent and identically distributed (i.i.d) cost-push shock with mean zero and variance σ_π^2. That is, $\xi_{\pi,t} \sim i.i.d.N(0, \sigma_\pi^2)$.[13]

2.5   The bank

The main role of the bank is to mediate funds between savers (patient households) and borrowers (impatient households and entrepreneurs). The bank chooses consumption ($C_{f,t}$) to maximise the expected discounted lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta_f^t (1-\eta_f)log(C_{f,t} - \eta_f C_{f,t-1}), \tag{32}$$

where β_f is the bank's subjective discount factor, such that $\beta_f < \beta_s$. Note that $C_{f,t}$ can be interpreted as dividends or profits generated by the bank, which are assumed to be fully consumed by the bank. $\eta_f C_{f,t-1}$ represents some form of dividend smoothing. The bank's budget constraint is given by:

$$C_{f,t} + \frac{R_{t-1}}{\pi_t}D_{t-1} + L_{b,t} + L_{e,t} + AC_{bf,t} + AC_{ef,t} = D_t + \frac{R_{b,t-1}}{\pi_t}(1-\zeta_{b,t})L_{b,t-1} + \frac{R_{e,t}}{\pi_t}(1-\zeta_{e,t})L_{e,t-1}, \tag{33}$$

---

[12]The profit function is given by: $P_t Y_t - \int_0^1 P_t(k)Y_t(k)$.

[13]Variables with a hat denote percent deviations from the steady state.

where D_t is the patient household's deposits. $L_{b,t}$ and $L_{e,t}$ are bank loans to impatient households and entrepreneurs, respectively. $AC_{bf,t} = \frac{\phi_{bf}}{2} \frac{(L_{b,t} - L_{b,t-1})^2}{L_b}$ and $AC_{ef,t} = \frac{\phi_{ef}}{2} \frac{(L_{e,t} - L_{e,t-1})^2}{L_e}$ are quadratic loan portfolio adjustment costs associated with household and entrepreneur loans, respectively. $\zeta_{b,t}$ and $\zeta_{e,t}$ are household and entrepreneur NPLs, respectively. For the bank, these represent loan losses that the bank incurs when the impatient households and the entrepreneurs default on their loan contracts.

In addition to the budget constraint, the bank faces a capital requirement constraint. In line with the Basel capital regulations, the bank capital requirement constraint states that the bank must finance a certain fraction (κ) of new loans by equity (retained earnings in this model). In other words, the regulation requires the bank to hold a capital-to-assets ratio greater than or equal to some predetermined ratio (κ). Let bank capital be $BK_t = L_t - E_t \zeta_{t+1} - D_t$.[14] The capital requirement constraint is given by:

$$\frac{L_t - E_t \zeta_{t+1} - D_t}{w_b \left(L_{b,t} - E_t \frac{R_{b,t}}{\pi_{t+1}} \zeta_{b,t+1} L_{b,t} \right) + w_e \left(L_{e,t} - E_t \frac{R_{e,t+1}}{\pi_{t+1}} \zeta_{e,t+1} L_{e,t} \right)} \geq \kappa, \tag{34}$$

where $\kappa \in (0,1)$ is the capital requirement ratio (CRR) and $L_t = L_{b,t} + L_{e,t}$ is total loans. $E_t \zeta_{t+1}$ represents the allowance for the expected loan losses. w_b and w_e are risk weights on household and entrepreneur loans, respectively. These parameters capture different degrees of risk associated with household and entrepreneur loans. The capital requirement constraint (34) can be rewritten as a borrowing constraint, as follows:

$$D_t \leq (1 - w_b \kappa) \left(L_{b,t} - E_t \frac{R_{b,t}}{\pi_{t+1}} \zeta_{b,t+1} L_{b,t} \right) + (1 - w_e \kappa) \left(L_{e,t} - E_t \frac{R_{e,t+1}}{\pi_{t+1}} \zeta_{e,t+1} L_{e,t} \right). \tag{35}$$

Eq. (35) states that the amount of deposits that the bank can take from the patient household cannot exceed a weighted sum of the bank's net assets (loans net of the expected loan losses), where the weights attached to the household loans and entrepreneur loans are $(1 - w_b \kappa)$ and $(1 - w_e \kappa)$, respectively. This constraint limits the extent to which the bank can take on leverage. The condition that $\beta_f < \beta_s$ ensures that the constraint (35) is always binding at the steady state. In the absence of this assumption, the bank may find that it is optimal to postpone current consumption indefinitely and accumulate capital to the point where the capital requirement constraint does not have force.

Let $U_{Cf,t} = \frac{1 - \eta_f}{C_{f,t} - \eta_f C_{f,t-1}}$ be the marginal utility of consumption and $\lambda_{f,t}$ be the multiplier on the bank's borrowing constraint (35). The first order conditions which define the bank's problem are as follows:

$$\beta_f E_t \left(\frac{U_{Cf,t+1}}{U_{Cf,t}} \frac{R_t}{\pi_{t+1}} \right) = 1 - \frac{\lambda_{f,t}}{U_{Cf,t}}, \tag{36}$$

$$\beta_f E_t \left(\frac{U_{Cf,t+1}}{U_{Cf,t}} \frac{R_{b,t}}{\pi_{t+1}} (1 - \zeta_{b,t+1}) \right) = 1 - E_t \left[(1 - w_b \kappa) \frac{\lambda_{f,t}}{U_{Cf,t}} \left(1 - \frac{R_{b,t}}{\pi_{t+1}} \zeta_{b,t+1} \right) \right] + \frac{\phi_{bf}}{L_b} (L_{b,t} - L_{b,t-1}), \tag{37}$$

$$\beta_f E_t \left(\frac{U_{Cf,t+1}}{U_{Cf,t}} \frac{R_{e,t+1}}{\pi_{t+1}} (1 - \zeta_{e,t+1}) \right) = 1 - E_t \left[(1 - w_e \kappa) \frac{\lambda_{f,t}}{U_{Cf,t}} \left(1 - \frac{R_{e,t+1}}{\pi_{t+1}} \zeta_{e,t+1} \right) \right] + \frac{\phi_{ef}}{L_e} (L_{e,t} - L_{e,t-1}), \tag{38}$$

---

[14] $E_t \zeta_{t+1} = E_t \left(\frac{R_{b,t}}{\pi_{t+1}} \zeta_{b,t+1} L_{b,t} + \frac{R_{e,t+1}}{\pi_{t+1}} \zeta_{e,t+1} L_{e,t} \right)$ is the expected loan losses on the bank's loan portfolio and $L_t - E_t \zeta_{t+1}$ is net loans.

Eq. (36) describes the bank's demand for deposits. Eqs. (37) and (38) are the bank's optimal conditions for supplying loans to households and entrepreneurs, respectively.

2.6 Monetary policy

Monetary policy is exemplified by a standard Taylor-type rule with interest rate smoothing as follows:[15]

$$R_t = R \left(\frac{R_{t-1}}{R} \right)^{\phi_r} \left[\left(\frac{\pi_t}{\pi} \right)^{\phi_\pi} \left(\frac{Y_t}{Y_{t-1}} \right)^{\phi_y} \right]^{(1-\phi_r)} e^{\xi_{r,t}}, \tag{39}$$

where ϕ_r is the degree of interest rate smoothing, ϕ_π and ϕ_y measure the response of the policy rate to inflation and output growth, respectively. R and π are steady-state values of R_t and π_t, respectively. $\xi_{r,t}$ is an i.i.d. monetary policy shock with mean zero and variance σ_r^2. That is, $\xi_{r,t} \sim i.i.d.N(0, \sigma_r^2)$.

2.7 Market clearing conditions and equilibrium

The aggregate resource constraint is obtained by adding together the budget constraints of all agents in the economy (households, entrepreneurs and the bank), including the profit functions of the retailers:

$$Y_t = C_{s,t} + C_{b,t} + C_{e,t} + C_{f,t} + Adj_t, \tag{40}$$

where $Adj_t = AC_{bf,t} + AC_{ef,t}$.

Total consumption is given by:

$$C_t = C_{s,t} + C_{b,t} + C_{e,t} + C_{f,t}. \tag{41}$$

The housing market clearing condition requires:

$$H_{s,t} + H_{b,t} + H_{e,t} = 1. \tag{42}$$

In the credit market, the total supply of loans equals the demand by impatient households and entrepreneurs:

$$L_t = L_{b,t} + L_{e,t}. \tag{43}$$

3 Estimation

In line with the literature (e.g., Quint and Rabanal, 2014; Bailliu et al., 2015; Gelain and Ilbas, 2017; Turdaliev and Zhang, 2019), we first estimate the model using South African data to pin down the values of the parameters that are not standard in the literature and to capture the silent features of the South African economy. We then use the parameter estimates obtained from the estimation to conduct simulation exercises in the rest of the paper. We estimate the model for the South African economy using Bayesian techniques as discussed in An and Schorfheide (2007).[16] In what follows, we briefly discuss the observable variables being used for estimation, the calibrated parameters, and the prior and posterior distribution of the parameters.

---

[15]This is consistent with monetary policy under an inflation-targeting regime such as the one the South African Reserve Bank has been following since 2000.

[16]We use Dynare (version 4.5.7) to estimate the model.

3.1 Data

We use quarterly data over the sample period 2000Q1–2016Q4, which coincides with the inflation-targeting monetary policy regime in South Africa. The model allows for a total of 8 shocks. In line with the standard practice in the DSGE literature, we have as many shocks as the number of observable variables in the data set. The observable variables are real gross domestic product (GDP) per capita, real household credit per capita, real corporate credit per capita, inflation rate, short-term nominal interest rate, real house prices, ratio of household NPLs to total household loans and ratio of corporate NPLs to total corporate loans.[17] Fig. 1 plots the transformed observable variables being used for estimation. Before proceeding with the estimation, we detrend the logarithm of real variables by taking the first-difference of each variable and subtracting the corresponding sample mean. Inflation, interest rate, ratios of household NPLs and corporate NPLs are demeaned. Most of the data are obtained from the South African Reserve Bank database. House price data are obtained from ABSA bank (one of the leading banks in South Africa), interest rate data from the International Monetary Fund's International Financial Statistics database, and population data from World Bank database.

3.2 Calibration

As is standard in Bayesian estimation of DSGE models, we calibrate a subset of parameters for which the data set being used for estimation cannot provide sufficient information. Some of these parameters are calibrated based on the data and steady state conditions of the model, while others are borrowed from the literature. These parameters are presented in Table 1.

The discount factor for patient households is set at $\beta_s = 0.995$, for impatient households at $\beta_b = 0.97$ and for entrepreneurs at $\beta_e = 0.96$. The choice of these values ensures that both impatient households' and entrepreneurs' borrowing constraints are binding in the neighbourhood of steady state. The steady-state value of the gross inflation rate is set at $\pi = 1.016$, which implies an annual inflation rate of 6.4% in the steady state, which is fairly in line with the data over the sample period. Together with patient households' discount factor, this value implies a steady-state nominal interest rate of 8.5% per annum, which is slightly higher than the sample mean from the data for the period 2000Q1–2016Q4.

The weight on leisure in the households' utility function is set at $\tau = 2$. This value implies that households devote approximately one third of their time to work in line with the literature. The share of housing in production is set at $\nu = 0.1$ in the ballpark of the values widely used in the literature for emerging market economies (e.g., Iacoviello and Minetti, 2006; Minetti and Peng, 2018). The housing weight in the utility functions is calibrated at $j = 0.12$. The choice of these values implies that in the steady state the share of households' housing wealth (residential housing wealth) to total housing wealth is 0.80 while the remaining share of 0.20 is entrepreneurs' housing wealth (commercial housing wealth). These values are fairly in line with the South African data on housing wealth.[18]

---

[17] In Appendix B, we present a more detailed description of the data.

[18] The 2016 Property Sector Charter Council's report suggests that residential housing wealth constitutes approximately 80% of the total South African housing wealth while the remainder is commercial housing wealth. Source: http://www.sacommercialpropnews.co.za/property-investment/8211-sa-property-sector-volumes-to-r5-8-trillion.html.
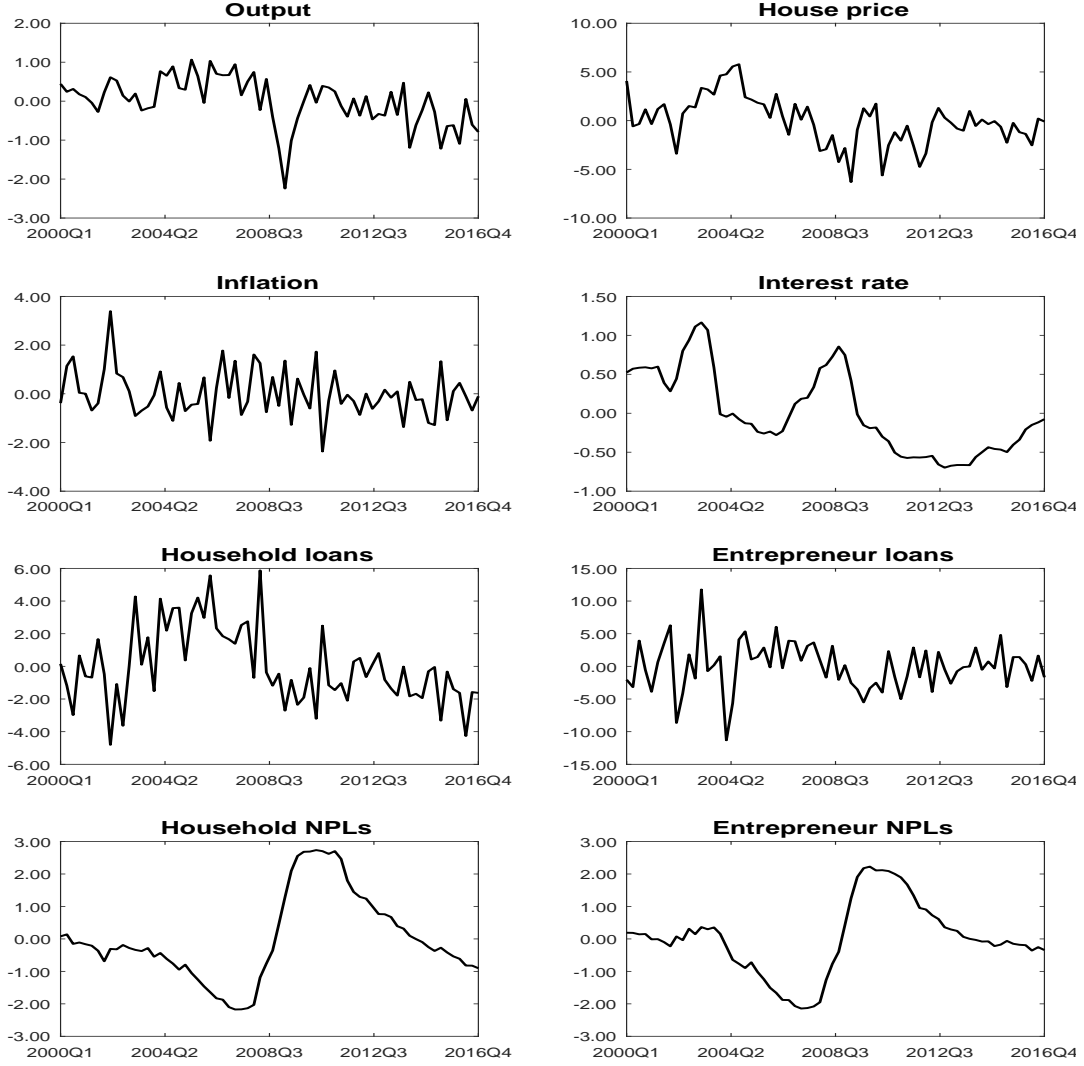
Figure 1: Observable variables. Note: Output, house prices, household loans and entrepreneur loans are demeaned percentage growth rates. Inflation rate, interest rate, ratios of household and entrepreneur (corporate) NPLs are in percentage deviations from their respective sample means.

Leverage ratios for impatient households and entrepreneurs are set based on the South African credit market data over the sample period. The steady-state LTV ratio for impatient households is set at $m_b = 0.8$. This value is fairly consistent with the minimum down-payment that South African banks require for providing home loans. For the entrepreneurs, the steady-state LTV ratio is set at $m_e = 0.6$. Both values are well within the observed maximum LTV ratios for a first-time mortgage buyer typically found in emerging and developing economies (see, e.g., IMF, 2011). These values pin down the steady-state ratio of household loans to output at 0.35 and of entrepreneur loans to output at 0.34, consistent with the South African credit market data.

The steady-state capital requirement ratio is set at $\kappa = 0.13$ to match the historical average observed in the South African banking data. The risk weights assigned to household and entrepreneur loans are both set at $w_b = w_e = 1$. The discount factor for banks is set at $\beta_f = 0.95$. This value is lower than the patient households' discount factor (β_s) and guarantees that the banks' borrowing constraint (35) is binding in the neighbourhood of the steady state. The steady-state ratios of household and entrepreneur

14

Table 1: Calibrated parameters.

Parameter	Symbol	Value	Parameter	Symbol	Value
Discount factor (patient HH)	β_s	0.995	NPL persistence (impatient HH)	$\rho_{\varepsilon b}$	0.7
Discount factor (impatient HH)	β_b	0.97	NPL persistence (Entrep.)	$\rho_{\varepsilon e}$	0.7
Discount factor (Entrep.)	β_f	0.96	Steady-state capital requirement ratio	κ	0.13
Discount factor (Bank)	β_b	0.95	Steady-state LTV ratio (impatient HH)	m_b	0.80
Housing preference	j	0.12	Steady-state LTV ratio (Entrep.)	m_e	0.60
Labor supply parameter	τ	2	Steady-state ratio of HH NPLs	ζ_b	0.04
Housing share in production	ν	0.1	Steady-state ratio of Entrep. NPLs	ζ_e	0.034
Risk weight (impatient HH loans)	w_b	1	Steady-state inflation	π	1.016
Risk weight (Entrep. loans)	w_e	1	Steady-state gross markup	X	1.10

Note: HH, Entrep and NPL stand for household, entrepreneur and non-performing loan.

NPLs are set at $\zeta_b = 0.04$ and $\zeta_e = 0.034$, respectively, matching their historical average values. Together with impatient households' and entrepreneurs' discount factors, these values imply the spread of more than 500 basis points between the effective lending rates (risk-adjusted lending rates) and deposit (policy) rate, which is broadly in line with the South African interest rate data.[19]

We set the steady-state gross markup at $X = 1.10$, which is in the ballpark of values widely used in the literature.[20] This implies a steady-state markup of 10% in the retail sector. The parameters measuring the persistence of household and entrepreneur NPLs are set at $\rho_{\varepsilon b} = \rho_{\varepsilon e} = 0.7$.

3.3 Prior distributions

Tables 2 and 3 report prior distributions, means and standard deviations of the remaining set of parameters to be estimated. The choice of these priors is guided by the DSGE literature, particularly in the context of South Africa.

The degree of habit persistence is assumed to follow a beta distribution with a mean of 0.5 and a standard deviation of 0.05. The parameter for the impatient household's labour income share is assumed to follow a beta distribution with a mean of 0.3 and a standard deviation of 0.02. These priors are based on Iacoviello (2015) and Gupta and Sun (2018). The priors for the parameters of the monetary policy rule are set as follows. The interest rate smoothing parameter is assumed to follow a beta distribution with a mean of 0.7 and a standard deviation of 0.05. The coefficients on inflation and output growth are assumed to follow a gamma and a normal distribution with means of 1.5 and 0.5, respectively, and a standard deviation of 0.05. These values are in line with Steinbach et al. (2009),Alpanda et al. (2010),Liu (2013) and du Plessis et al. (2014).

The elasticities of household and entrepreneur NPLs with respect to output are assumed to follow a beta distribution with a mean of 0.5 and a standard deviation of 0.1. This is in line with Steinbach et al. (2014). The prior mean for these parameters is also consistent with the estimated elasticity of NPLs

---

[19]The risk-adjusted lending rate or effective lending rate is approximated by the average of a sum of lending rates, as reported by the South Africa Reserve Bank, and ratios of NPLs.

[20]For the case of South Africa, see for example Liu and Seeiso (2012) and Gupta and Sun (2018).

with respect to output growth across major developing economies, including South Africa, in Glen and Mondragón-Vélez (2011). The parameters governing household and entrepreneur default costs (ϑ_b and ϑ_e) follow a beta distribution with a mean of 0.5 and a standard deviation of 0.2, in line with Zhang (2019). The loan portfolio adjustment cost parameters are assumed to follow a gamma distribution with a mean of 0.25 and a standard deviation of 0.125, in line with Iacoviello (2015).

The persistence of all structural shocks is assumed to follow a beta distribution with a mean of 0.8 and a standard deviation of 0.1 in line with the literature (e.g., Steinbach et al., 2009; Alpanda et al., 2010; Gupta and Sun, 2018). The standard deviation of the shocks is assumed to follow an inverse gamma distribution with a mean of 0.1 and standard deviation of 0.25.

Table 2: Prior and posterior distributions of the structural parameters.

Parameter		Prior distribution			Posterior distribution		
		Density	Mean	St.dev.	5 %	Mean	95 %
Habit persistence	η	beta	0.50	0.05	0.5257	0.5609	0.5959
Impatient HH income share	σ	beta	0.30	0.02	0.2250	0.2412	0.2581
Calvo parameter	θ	beta	0.65	0.02	0.4693	0.5057	0.5435
Price indexation	ι_π	beta	0.50	0.05	0.3030	0.3884	0.4787
Interest rate smoothing	ϕ_r	beta	0.70	0.05	0.4085	0.4688	0.5266
Taylor coefficient on inflation	ϕ_π	gamma	1.70	0.05	1.6071	1.7016	1.7965
Taylor coefficient on output	ϕ_y	normal	0.50	0.05	0.4752	0.5589	0.6437
Elasticity of HH NPLs w.r.t output	$\chi_{\zeta b}$	gamma	0.50	0.10	0.3010	0.4916	0.6821
Elasticity of Entrep. NPLs w.r.t output	$\chi_{\zeta e}$	gamma	0.50	0.10	0.2749	0.4468	0.6228
HH default cost parameter	ϑ_b	beta	0.50	0.10	0.5954	0.7042	0.8108
Entrep. default cost parameter	ϑ_e	beta	0.50	0.10	0.0640	0.1287	0.2024
Impatient HH loan adj. cost	ϕ_{bf}	gamma	0.25	0.125	0.9309	1.0396	1.1500
Entrep. loan adj. cost	ϕ_{ef}	gamma	0.25	0.125	0.0061	0.0281	0.0542

Notes: The posterior density is constructed by simulation using the Random-Walk Metropolis algorithm (two chains with 250,000 draws each). HH, Entrep. and NPL stand for household, entrepreneur and non-performing loan.

3.4 Posterior estimates

The last three columns of Tables 2 and 3 show the posterior mean and the 5 and 95 percentiles of the posterior distributions of the estimated parameters.[21] The habit persistence parameter is estimated at 0.56 and the impatient households' labour income share parameter at 0.24. These values are fairly in line with the estimated values in Iacoviello (2015) and Gupta and Sun (2018). The Calvo parameter, which measures the degree of price stickiness, is estimated at 0.51. This implies that entrepreneurs adjust prices approximately every 2 quarters. The results also imply a moderate degree of price indexation to the past inflation, at the estimated value of 0.39, for entrepreneurs who do not adjust prices every quarter.

Turning to the parameters governing the monetary policy rule, we find that the parameters for the response of the policy rate to inflation and output growth (Taylor coefficients) are $\phi_\pi = 1.70$ and

---

[21]We present the prior and posterior marginal densities of the structural parameters, the multivariate convergence diagnostics plots, the identification test results, the log-posterior likelihood functions and log-likelihood kernels of the estimated parameters in a technical appendix. Results for the impulse response functions (IRFs) analysis and the historical shock decomposition analysis are reported in the technical appendix. The technical appendix is available upon request.

Table 3: Prior and posterior distributions of the shocks.

Parameter		Prior distribution			Posterior distribution		
		Density	Mean	St.dev.	5 %	Mean	95 %
AR(1) coefficients							
Housing demand shock	ρ_j	beta	0.80	0.10	0.9896	0.9929	0.9959
Technology shock	ρ_z	beta	0.80	0.10	0.9864	0.9924	0.9977
HH LTV shock	$\rho_{\gamma b}$	beta	0.80	0.10	0.8924	0.9342	0.9748
Entrep. LTV shock	$\rho_{\gamma e}$	beta	0.80	0.10	0.9252	0.9483	0.9695
Standard deviations							
Housing demand shock	σ_j	invg	0.10	0.25	0.0282	0.0367	0.0456
Technology shock	σ_z	invg	0.10	0.25	0.0099	0.0108	0.0118
HH LTV shock	$\sigma_{\gamma b}$	invg	0.10	0.25	0.0174	0.0197	0.0220
Entrep. LTV shock	$\sigma_{\gamma e}$	invg	0.10	0.25	0.0165	0.0177	0.0189
Monetary policy shock	σ_r	invg	0.10	0.25	0.0078	0.0088	0.0098
Cost-push shock	σ_π	invg	0.10	0.25	0.0120	0.0138	0.0155
HH NPL shock	$\sigma_{\varepsilon b}$	invg	0.10	0.25	0.1038	0.1172	0.1307
Entrep. NPL shock	$\sigma_{\varepsilon e}$	invg	0.10	0.25	0.1227	0.1434	0.1656

Notes: The posterior density is constructed by simulation using the Random-Walk Metropolis algorithm (two chains with 250,000 draws each). HH, Entrep. and NPL stand for household, entrepreneur and non-performing loan. AR stands for autoregressive.

$\phi_y = 0.56$, respectively. The results also suggest that there is a modest degree of interest rate smoothing, estimated at $\phi_\pi = 0.47$. These values are fairly in line with the Taylor principle and the South African literature (see for e.g., Steinbach et al., 2009; Liu, 2013). The elasticities of household and entrepreneur NPLs with respect to output growth are 0.49 and 0.45, respectively. These values are fairly in line with the estimated value in Glen and Mondragón-Vélez (2011) for emerging markets. The default cost parameter for impatient households is 0.70 and for entrepreneurs 0.13. This implies that, in the event of loan default, impatient households use approximately 70% of transfers of wealth from the bank to pay the costs associated with default, whereas entrepreneurs use only 13% of transfers of wealth to pay the default costs.

4 Business cycle properties

In this section we assess the performance of the estimated model. Specifically, we evaluate how well the model conforms to the actual data in terms of standard deviation and correlation of key variables with output.

Table 4 shows that the estimated model does a fairly good job of matching the data moments. The model reproduces the standard deviations of house prices, inflation and the policy rate fairly in line with the data. It also does a reasonably good job of reproducing the standard deviations of output, household loans and corporate loans, but somewhat overstates them. Importantly, the model does a good job in reproducing the fact that entrepreneur loans are more volatile than household loans, and

Table 4: Business cycle properties.

Variable	Standard deviation		Correlation with output	
	Data	Model	Data	Model
Output	0.61	0.96	1.00	1.00
House prices	2.44	2.33	0.42	0.72
Inflation	0.96	0.99	-0.03	-0.50
Policy rate	0.51	0.63	0.10	-0.70
Household loans	2.28	3.12	0.46	0.55
Entrepreneur loans	3.60	6.41	0.09	0.54

Notes: We do not report the business cycle properties for household and entrepreneur NPLs because we have used proxies for these two variables.

also the fact that entrepreneur loans, household loans, house prices and inflation are more volatile than output, while the policy rate is less volatile than output. Turning to the correlation of the variables with output, the results show that the model reproduces a strong correlation of output with house prices and household loans, consistent with the data. Although the model overestimates the correlation of output with corporate loans and inflation, it does a good job of predicting a countercyclical (negative correlation with) inflation and a procyclical (positive correlation with) corporate loans. However, the model fails to reproduce the positive correlation of output with the policy rate. In general, the estimated model does a reasonably good job of matching the stylised facts observed in the South African data over the period 2000Q1–2016Q4.

5 Optimal monetary and macroprudential policy

In this section we investigate the optimal design and effectiveness of a simultaneous deployment of monetary and macroprudential policies in promoting macroeconomic and financial stability. To conduct this analysis, we set the model parameters at their posterior means obtained from the estimation and use the optimal simple rule (OSR) optimisation routine in Dynare to derive the optimal monetary and macroprudential policy parameters. In what follows, we first describe the loss function and policy regimes to be used for the optimal simple rule analysis and then report the results of the OSR analysis.

5.1 Policy loss function

To find the optimal policy, following Angelini et al. (2014) and Agénor et al. (2018), we assume the central bank minimises the quadratic welfare loss function in terms of a weighted sum of the volatilities of inflation, output, credit-to-output ratio and house prices as follows:

$$\mathcal{L} = \sigma_\pi^2 + \lambda_y \sigma_y^2 + \lambda_{l/y} \sigma_{l/y}^2 + \lambda_q \sigma_q^2, \tag{44}$$

where σ_π^2, σ_y^2, $\sigma_{l/y}^2$ and σ_q^2 are the volatilities of inflation, output, credit-to-output ratio and house prices, respectively. Parameters $\lambda_y, \lambda_{l/y}, \lambda_q \geq 0$ are the relative weights of output, credit-to-output ratio and house prices in the loss function, respectively. To simplify our analysis, we conduct policy experiments

with the weights of $\lambda_y = 0.5$, $\lambda_{l/y} = 0.5$ and $\lambda_q = 0.05$ in the loss function.[22] We assign a lower weight to output than to inflation, to reflect South Africa's inflation-targeting monetary policy regime over the sample period. We assign a lower weight to the volatility of house prices than to the volatility of credit-to-output ratio, based on the empirical evidence that fluctuations in credit-to-output ratio are more important than fluctuations in asset prices in predicting financial distress (Agénor and Pereira da Silva, 2017; Agénor et al., 2018). We only consider the case where there is a single policymaker (a central bank) that pursues both macroeconomic and financial stability objectives using the two policy instruments – the policy rate and the capital requirement ratio. That is, we assume that monetary and macroeconomic policies are conducted under full coordination.

5.2 Policy regimes

To study the effectiveness of a joint implementation of monetary and macroprudential policies, we assess two alternative policy regimes (II and III) against a benchmark regime (I). The benchmark regime is described by the standard Taylor rule (39), and a constant capital requirement ratio without the macroprudential policy rule, i.e. the countercyclical capital requirement (CcCR).

Regime II is a combination of the standard Taylor rule (39) and the CcCR which relates the capital requirement ratio to the credit-to-output gap as follows:

$$\kappa_t = \kappa \left(\frac{L_t/Y_t}{L/Y} \right)^{\chi_l}, \tag{45}$$

where κ is the steady-state value of capital requirement ratio. Y and L are steady-state values of output and total loans, respectively. $\chi_l \geq 0$ measures the extent to which capital requirement ratio reacts to the credit-to-output gap. The CcCR rule is consistent with the main objective of macroprudential policy: to protect the banking sector from excessive fluctuations in the credit-to-output ratio which could have dire consequences for financial stability and negative spillover on the real economy.

Regime III is a combination of the CcCR rule (45) and an augmented Taylor rule as follows:

$$R_t = R \left(\frac{R_{t-1}}{R} \right)^{\phi_r} \left[\left(\frac{\pi_t}{\pi} \right)^{\phi_\pi} \left(\frac{Y_t}{Y_{t-1}} \right)^{\phi_y} \left(\frac{L_t}{L_{t-1}} \right)^{\phi_l} \right]^{(1-\phi_r)}, \tag{46}$$

where ϕ_l measures the extent to which the policy rate reacts to credit growth. The choice of credit growth rather than other financial variables such as house prices is motivated by the empirical findings in the literature that excessive fluctuations in a measure of credit (credit growth or credit-to-output ratio) is a robust indicator of a buildup of systemic risk (e.g., Schularick and Taylor, 2012; Gourinchas and Obstfeld, 2012; Mallick and Sousa, 2013; Jordà et al., 2015; Taylor, 2015). Furthermore, credit-driven bubbles are easier to measure, monitor, predict and control than asset price bubbles (Verona et al., 2017).

We then compute the optimal combination of the policy parameters $(\phi_\pi^*, \phi_y^*, \phi_l^*, \chi_l^*)$ in Eqs. (39), (45) and (46) by minimising the welfare loss function Eq. (44), subject to the constraints given by the model.[23]

---

[22]We also perform additional experiments with different weights on the volatilities of output and credit-to-output ratio in the ranges $\lambda_y = [0.5, 1]$ and $\lambda_l = [0.1, 1]$. The results are very similar to those reported here.

[23]As in Bailliu et al. (2015), we fix the smoothing parameter (ρ_r) at the estimated value to avoid a highly volatile policy rate and optimise over other policy parameters in the Taylor rule.

We perform the grid search over the ranges $\phi_\pi = [1.1, 3]$, $\phi_y = [0, 1]$, $\phi_l = [0, 0.2]$, $\chi_l = [0, 10]$, following the literature (see for e.g., Schmitt-Grohé and Uribe, 2007; Lambertini et al., 2013; Bailliu et al., 2015; Verona et al., 2017). We set the upper bound for ϕ_l to be less than that for ϕ_π because the primary objective of monetary policy is price stability. We assume that monetary policy provides a supporting role only to the financial stability objective. On the other hand, we set the upper bound for χ_l higher because the primary objective of macroprudential policy is financial stability.

5.3 Optimal simple rules

In this section we present the results of the optimal policy analysis: the optimal combination of policy parameters, welfare gain or loss, and standard deviations of the variables in the loss function relative to those under the benchmark regime. The top panel of Table 5 shows the results of the optimal combination of a standard monetary policy rule and a macroprudential policy rule (regime II) while the bottom panel shows those of the optimal combination of an augmented monetary policy rule and the macroprudential policy rule (regime III). To provide a more intuitive analysis, we conduct the optimal policy analysis conditional on specific shocks: housing demand shock (column 2), LTV shocks (column 3) and NPL shocks (column 4). The choice of these shocks is motivated by the findings in the literature that macroprudential policies are effective in mitigating the impact of financial shocks, but inefficient for non-financial shocks (Kannan et al., 2012; Angelini et al., 2014; Benes and Kumhof, 2015). For robustness purposes we also conduct the analysis for a technology shock in columns 5 and for all the shocks considered in the paper in column 6. As mentioned previously, we set all other parameters at their posterior means from the estimation.

The results show that both the optimal standard monetary policy rule and the optimal augmented monetary policy rule feature a moderate reaction to inflation in the ranges of 1.1 to 1.5, which are lower than the estimated value of 1.70. This implies that a strong reaction to inflation is not optimal when the central bank pursues both financial and macroeconomic stability mandates using the two policy instruments. These results hold across the five shock scenarios. It is also evident that the optimal standard and augmented monetary policy rules feature a stronger response to output than the estimated response of 0.56 under the benchmark regime. The optimal coefficient on output remains virtually unchanged across the five shock scenarios, especially under regime II. Across all the shock scenarios, the optimal coefficient on credit growth hits the upper bound of 0.2. Regarding the optimal design of macroprudential policy, the results suggest that the central bank should adjust the capital requirement ratio proportionately to the credit-to-output gap (i.e., $\chi_l \approx 1$). These results hold in both regime II and regime III and regardless of the source of the shock.

Turning to the welfare effect, the results suggest that the optimal combination of the monetary policy (standard or augmented) rule and the macroprudential policy rule enhances the central bank's ability to minimise the welfare loss. In comparison to the benchmark regime, both regimes II and III yield welfare gains regardless of the source of shock. Such welfare gains are far larger under regime III than under regime II.

It is evident that under regime II the welfare gains are mainly coming from the reduced volatilities

Table 5: Optimal policy parameters, welfare and standard deviations.

Parameter	Housing demand shock	LTV shocks	NPL shocks	Technology shock	All shocks
Regime II ($\phi_r = 0.47$):					
ϕ_π	1.20	1.10	1.10	1.10	1.16
ϕ_y	1.00	1.00	1.00	1.00	1.00
χ_l	1.12	1.12	1.12	1.12	1.12
Welfare gain (%)	23.09	26.19	21.39	10.11	20.03
Standard deviation relative to benchmark					
π_t	2.20	1.40	1.67	2.59	1.45
Y_t	0.90	0.71	0.75	0.98	0.97
L_t/Y_t	0.86	0.86	0.89	0.27	0.84
q_t	0.99	0.76	0.75	0.99	0.99
Regime III ($\phi_r = 0.47$):					
ϕ_π	1.25	1.31	1.53	1.10	1.25
ϕ_y	1.00	1.00	1.00	0.93	1.00
ϕ_l	0.20	0.20	0.20	0.20	0.20
χ_l	1.12	1.12	1.12	1.12	1.12
Welfare gain (%)	33.52	40.27	30.33	10.32	28.14
Standard deviation relative to benchmark					
π_t	5.60	4.20	2.00	2.78	1.51
Y_t	0.83	0.54	0.75	0.97	0.97
L_t/Y_t	0.79	0.77	0.83	0.29	0.77
q_t	0.99	0.78	0.92	0.98	0.99

Notes: Welfare gain is calculated as the percentage difference between welfare loss under the benchmark regime and an alternative policy regime (II or III). That is, $Welfare\ gain = 100 * \left[(\mathcal{L}_{benchmark} - \mathcal{L}_{alternative})/\mathcal{L}_{benchmark} \right]$. A positive value implies a welfare gain under an alternative regime. The standard deviation relative to the benchmark is calculated by dividing the standard deviation of a given variable i, $i = \{\pi, y, l/y, q\}$, under an alternative regime by the standard deviation under the benchmark regime. That is, $\sigma^2_{i,alternative}/\sigma^2_{i,benchmark}$. A value less than 1 means that an alternative regime reduces the volatility of variable i relative to the benchmark regime.

of output, credit-to-output ratio and house prices. The volatility of inflation, however, increases. This trade-off between financial stability and price stability worsens under regime III where the central bank adjusts the policy rate to credit growth in addition to inflation and output growth. In this case, the increase in financial stability comes at the cost of a much larger increase in the volatility of inflation. These findings are consistent with Gelain et al. (2013) and Tayler and Zilberman (2016), in which the authors note that a policy regime that combines an augmented monetary policy and macroprudential policy generates a trade-off between price and financial stability. In separate experiments, we set the upper bound for ϕ_l greater than 0.2. The results of these experiments are very similar to those reported here. The only difference is that financial stability benefits increase further at a much higher cost of increasing volatility of inflation than reported here. Furthermore, such experiments result in large values of the optimal policy coefficients on credit growth, in which case the objective of financial stability dominates that of price stability in the setting of the policy rate. We try to avoid such unrealistic scenario in our analysis. Besides, Schmitt-Grohé and Uribe (2007) note that large values of the optimal policy coefficients are difficult to communicate to policymakers or the public.[24]

6   Impulse response analysis

To gain more insights into how monetary policy interacts with macroprudential policy, we present the impulse responses of the key variables following housing demand, LTV and NPL shocks. We contrast the benchmark regime with the two alternative policy regimes. We use the parameter values derived from the optimal rule analysis reported in Table 5 for the parameters in the monetary policy and macroprudential policy rules. We set other parameter values at their posterior means obtained from the estimation.

Fig. 2 shows the impulse responses of the key variables following a positive housing demand shock. Under the benchmark regime, the shock generates expansionary effects in the economy. It increases house prices and, through collateral constraints, leads to an increase in both household loans and entrepreneur loans. This in turn stimulates consumption and output growth. The policy rate increases and inflation decreases. Lending rates increase following the increase in demand for loans. When the central bank adopts regime II, we see the expansionary effect of the housing demand shock is dampened. The central bank increases the capital requirement ratio as the credit-to-output ratio increases. This prompts the bank to adjust its balance sheet by reducing the supply of credit (loans) relative to the supply under the benchmark regime. The reduction in credit supply induces borrowers to reduce their demand for housing. This dampens the increase in house prices and thus mitigates the amplification effect of the borrowing constraints. Consequently, consumption and output do not increase as much as under the benchmark regime.

Regime III significantly attenuates the expansionary effect of the shock, mainly through two channels. First, it works through the intertemporal substitution effect of the monetary policy on savers. The further increase in the policy rate prompts patient households to substitute from consumption to savings.

---

[24] Agénor et al. (2013) also note that allowing the policy rate to react aggressively to financial variables (credit growth or credit-to-output ratio) increases the volatility of the policy rate which could be a concern for the central bank as it could generate instability in the economy.
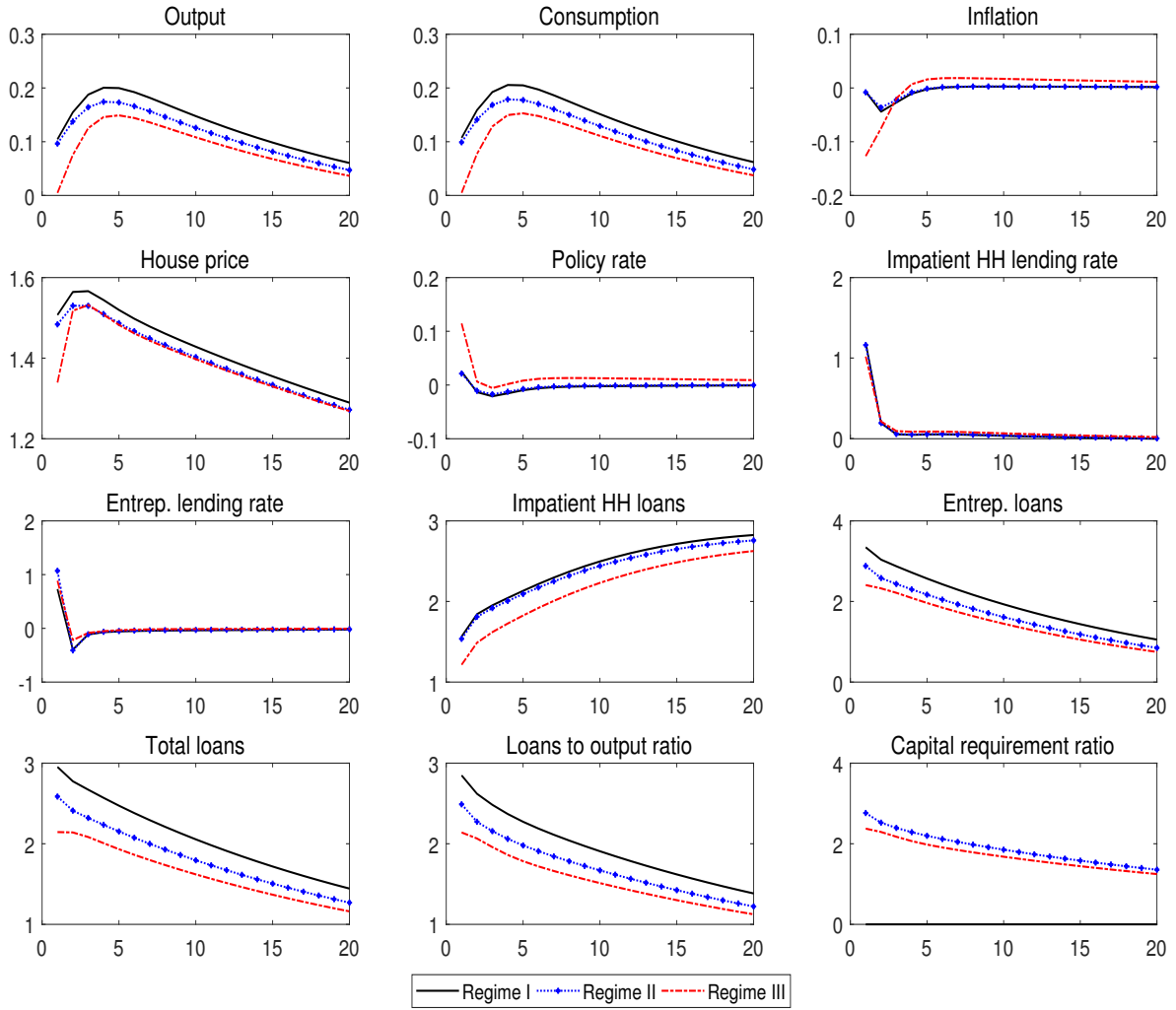
Figure 2: Impulse responses to a positive housing demand shock under different policy regimes: Benchmark regime I (standard Taylor rule), regime II (standard Taylor rule and CcCR) and regime III (augmented Taylor rule and CcCR). Aggregate variables are expressed in % deviations from the steady state, and interest rates and inflation are in percentage point deviations from the steady state. HH and Entrep. stand for household and entrepreneur. *Ordinate*: time horizon in quarters.

This causes the increase in aggregate consumption and output to decline under regime III. Second, it works through the expectation effect of the monetary policy. Intuitively, in a policy regime where monetary policy also responds to credit growth, private agents would expect the policy rate to react more aggressively than in a policy regime where monetary policy does not respond to financial conditions. Under regime III, forward-looking borrowers take into account the potential further increase in the policy rate when making economic decisions, and react by borrowing less. Hence, household loans and entrepreneur loans increase much less than under regime II. This in turn helps the central bank to implement a relatively easier macroprudential policy. In other words, the augmented Taylor rule helps to foster financial stability.

The attenuation effect of regime III, however, does not come for free. Consistent with the findings in the previous section, it is evident that the central bank faces a more severe trade-off between price and

financial stability under regime III. A further increase in the policy rate stabilises credit market, house prices and output, but exacerbates the fluctuation of inflation. This suggests that regime III creates conflicts between price and financial stability objectives. The fall in inflation requires the central bank to reduce the policy rate, while the credit market boom requires the central bank to increase it. However, this policy conflict is absent under regime II because here monetary policy focuses solely on its primary objective of price stability, not financial stability.

We now turn to the impact of the credit market shocks (household LTV and NPL shocks). Fig. 3 shows the impulse response functions (IRFs) of the key variables following a positive household LTV shock.[25] Under the benchmark regime, the shock increases the borrowing capacity of impatient households and leads to an increase in the demand for housing and an increase in house prices. Both impatient households and entrepreneurs increase their demand for loans and thus stimulate aggregate spending and production. The increase in demand for loans prompts banks to increase the lending rates. The expansionary effect of the shock pushes up inflation. The policy rate increases initially to counteract the increase in inflation.

As in the case of the housing demand shock, a simultaneous deployment of monetary and macro-prudential policies dampens the expansionary effects of the LTV shock. Under regime II, the central bank tightens the capital requirement regulation when the credit-to-output ratio increases. This induces the bank to adjust its balance sheet by reducing the supply of loans to impatient households and entrepreneurs. As a result, both impatient households and entrepreneurs reduce spending, including investment in housing. This in turn dampens the increase in house prices and thus mitigates the amplification effect of the borrowing constraint on the real sector. As a consequence, consumption and output increase by less under regime II than under the benchmark regime.

The results suggest that regime III is more effective than regime II in dampening fluctuations in total loans, house prices, consumption and output following a positive household LTV shock. As in the case of the housing demand shock, this attenuation effect comes at a higher cost in terms of the trade-off between price and financial stability. Specifically, regime III enhances financial stability at the cost of destabilising inflation.

In Fig. 4 we compare the responses of the key variables to a negative household NPL shock under the three policy regimes.[26] The shock affects financial variables mainly through the bank balance sheet channel. Under the benchmark regime, the shock increases the ratio of impatient households' NPLs and leads to an increase in the banks' loan losses. This in turn reduces the banks' net worth (bank capital) and forces them to reduce the total supply of loans in order to meet the capital requirement. Because the NPL shock occurs in the household loan sector of the credit market, the decrease in household loans is much larger than that in entrepreneur loans.

---

[25] For brevity, we report only the impulse response functions to a positive household LTV shock. Similar results as those reported here also hold for the case of a positive entrepreneur LTV shock. The only notable difference is that impatient household lending rate declines under regime III in the case of a shock to entrepreneur LTV. The results are reported in technical appendix E.

[26] For brevity, we report only the impulse responses of the key variables to a negative household NPL shock. The results for a negative entrepreneur NPL shock are qualitatively similar to those reported here. The results are reported in technical appendix E.
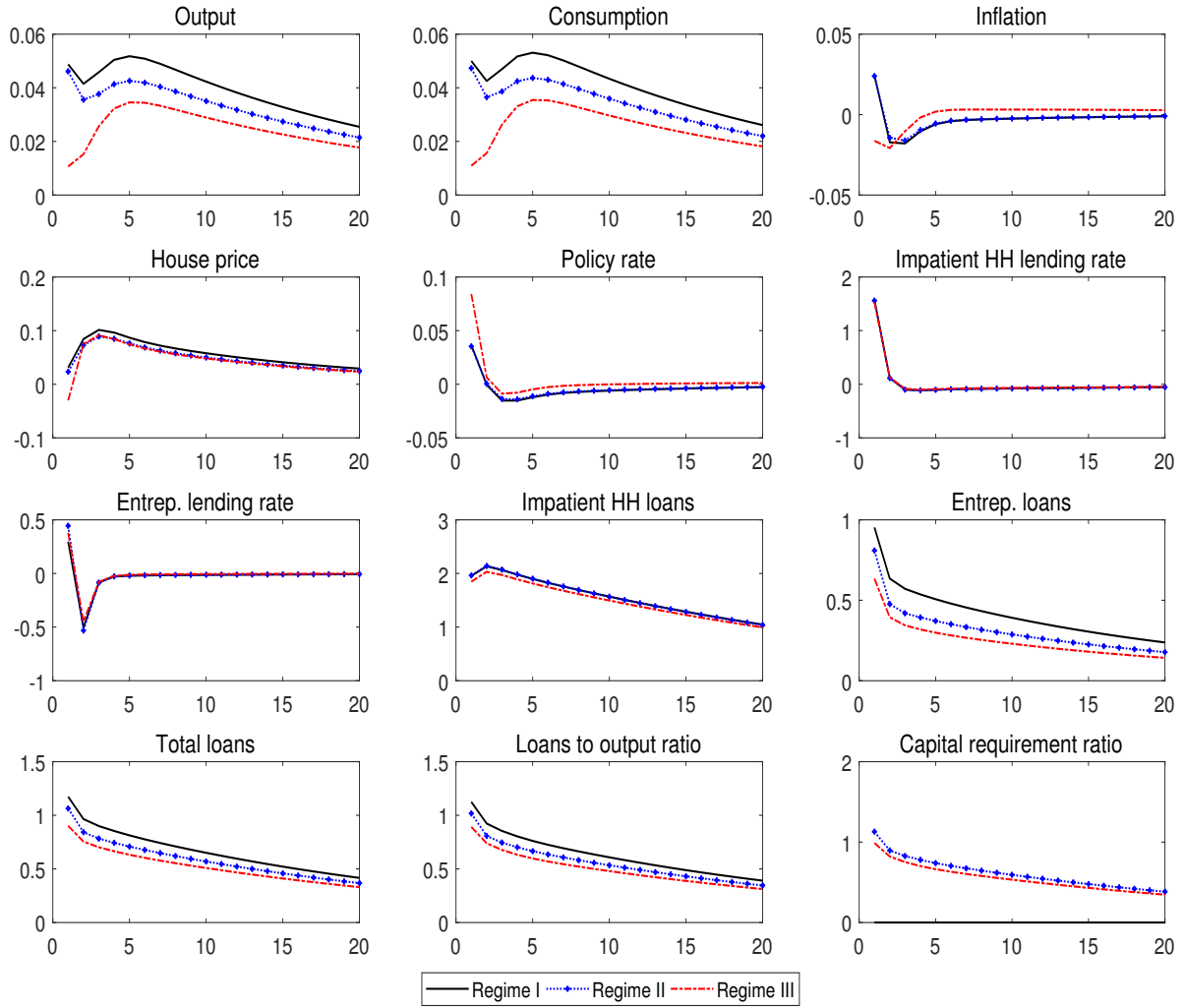
Figure 3: Impulse responses to a positive household LTV shock under different policy regimes: Benchmark regime I (standard Taylor rule), regime II (standard Taylor rule and CcCR) and regime III (augmented Taylor rule and CcCR). Aggregate variables are expressed in % deviations from the steady state, and interest rates and inflation are in percentage point deviations from the steady state. HH and Entrep. stand for household and entrepreneur. *Ordinate*: time horizon in quarters.

In addition to this indirect effect stemmed from the balance sheet adjustment, the shock prompts the banks to increase lending rates in response to an increase in the perceived credit risk and in an attempt to rebuild their net worth by increasing interest rate earnings. This further weakens the demand for loans, and prompts borrowers to reduce spending, including investment in housing. House prices decrease as the demand for housing falls, and this generates a negative housing wealth effect, leading to a fall in consumption and output. The central bank increases the policy rate to counteract the increase in inflation.

Regime II dampens the negative impact of the shock. In this case, the central bank relaxes the capital requirement regulation as credit-to-output ratio declines. This reduces the pressure on banks to adjust their balance sheet as aggressively as under the benchmark regime. As a result, total loans fall by less under regime II than under the benchmark regime. This mitigates the spillover effects of the shock on

the housing market and the real sector. As a consequence, house prices, consumption and output decline by less under regime II than under the benchmark regime.
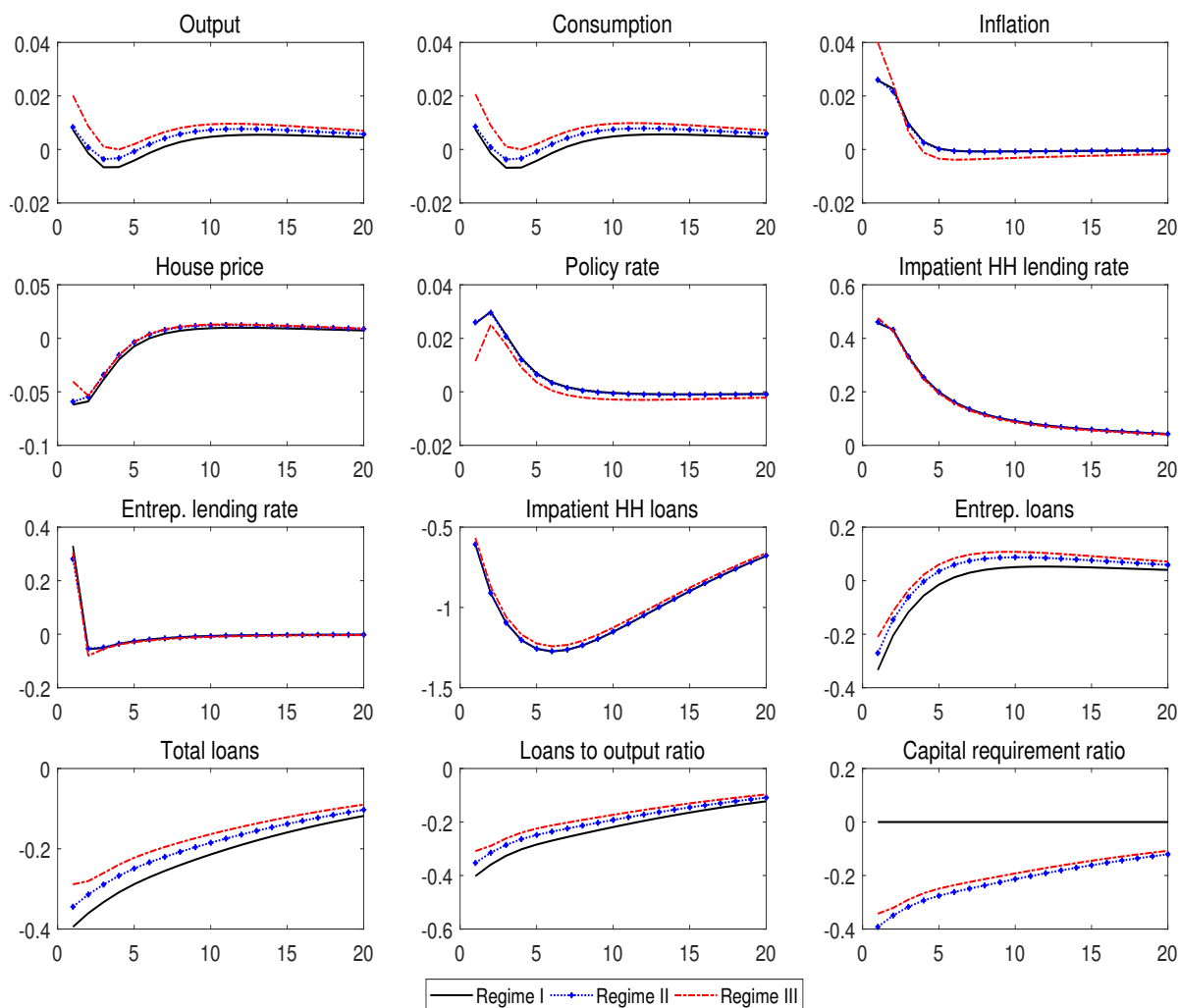

Figure 4: Impulse responses to a negative shock to impatient household non-performing loans under different policy regimes: Benchmark regime I (standard Taylor rule), regime II (standard Taylor rule and CcCR) and regime III (augmented Taylor rule and CcCR). Aggregate variables are expressed in % deviations from the steady state, and interest rates and inflation are in percentage point deviations from the steady state. HH and Entrep. stand for household and entrepreneur. *Ordinate*: time horizon in quarters.

Fig. 4 also shows that regime III enhances this stabilisation effect through the expectation channel of monetary policy and the intertemporal substitution effect of monetary policy. In this case, the policy rate increases less than under regime II. This is because the policy rate also responds to the decline in credit growth. Because of a smaller increase in the policy rate, inflation increases more under regime III than under regime II. As a result, the real interest rate decreases more and this in turn prompts patient households to increase consumption and reduce investment in housing due to the intertemporal substitution effect. In the anticipation of a smaller increase in the policy rate, both types of borrowers increase their borrowing. Consequently, impatient households' and entrepreneurs' spending, including investment in housing, fall by less under regime III than that under regime II. This mitigates the fall

in house prices and, through the borrowing constraint, mitigates the negative impact of the shock on the real sector. Similar to the cases of housing demand shock and LTV shock, we find that regime III outperforms regime II in dampening fluctuations in the credit market, the housing market and the real sector. But this comes at the expense of increasing fluctuations in inflation.

The main conclusions we can draw from this analysis are as follows. A policy regime that combines a standard monetary policy rule and a macroprudential policy rule delivers a more stable economic system than a regime that combines an augmented monetary policy rule and a macroprudential policy rule. The central bank faces a trade-off between price and financial stability objectives when monetary policy also responds to credit growth. While this policy regime seems to be effective from the financial stability point of view, it can compromise price stability, as noted by Tayler and Zilberman (2016). This is especially the case when shocks generate a negative correlation between credit and inflation. As noted in our analysis, a housing demand, LTV or NPL shock generates a negative correlation between credit and inflation. The central bank is forced to choose between price stability and financial stability when deploying an augmented monetary policy rule. The policy rate response required to achieve price stability is inconsistent with that required to achieve financial stability. For example, a positive housing demand shock increases credit but reduces inflation. While the fall in inflation calls for a reduction in the policy rate, a boom in the credit market calls for an increase. The opposite is also true in the case of a negative shock. As we have seen in the impulse response analysis, this conflict compromises the central bank's ability to deliver on its price stability mandate. Nevertheless, the trade-off between price and financial stability is minimised and the policy conflict is absent under regime II.

7 Efficient policy frontiers

In this section we compare the three policy regimes in terms of two-dimensional efficient policy frontiers. The efficient policy frontier shows the locus of the volatilities of key policy variables (inflation and credit-to-output ratio), calculated for each set of optimal policy coefficients that are obtained for different combinations of loss function weights. To perform the exercise, we simplify the loss function (44) by setting the weights on the volatilities of output and house prices to 0.5 and 0.1 ($\lambda_y = 0.5$ and $\lambda_q = 0.1$), respectively, and allow the weight on the volatility of credit-to-output ratio to vary within the range $\lambda_{l/y} \in [0,\ 1]$. That is,

$$\mathcal{L} = \sigma_\pi^2 + 0.5\sigma_y^2 + \lambda_{l/y}\sigma_{l/y}^2 + 0.1\sigma_q^2. \tag{47}$$

Fig. 5 shows the efficient policy frontiers when the economy faces housing demand, LTV and NPL shocks considered in the previous section. Moving from right to left in Fig. 5, the weight on the volatility of credit-to-output ratio ($\lambda_{l/y}$) increases from 0 to 1. A curve closer to the origin represents a more efficient (preferred) policy regime. We see that the introduction of macroprudential policy enhances both financial and price stability, especially regime II. That is, given a same weight on the volatility of credit-to-output ratio ($\lambda_{l/y}$) in the loss function, regime II delivers a more efficient policy outcome in terms of a lower volatility of inflation and the credit-to-output ratio. A comparison between regime II and regime III suggests that regime III is more effective than regime II in promoting financial stability.

However, this can only be achieved at a much higher cost of price stability.

The efficient policy frontiers under the three policy regimes present a clear trade-off between inflation and credit-to-output ratio volatilities, as the central bank adjusts its preference for stabilising the credit-to-output ratio relative to stabilising inflation. The maximum attainable reduction in credit-to-output volatility can be achieved at the expense of increasing inflation volatility, especially under regime III. Moveover, the relatively inelastic efficient policy frontiers, especially when the economy faces a housing demand shock, imply that it is not wise for the central bank to put a relatively high weight on the credit-to-output ratio in its loss function. This is because a marginal reduction in the volatility of credit-to-output ratio is achieved at a relatively high cost in terms of the volatility of inflation.
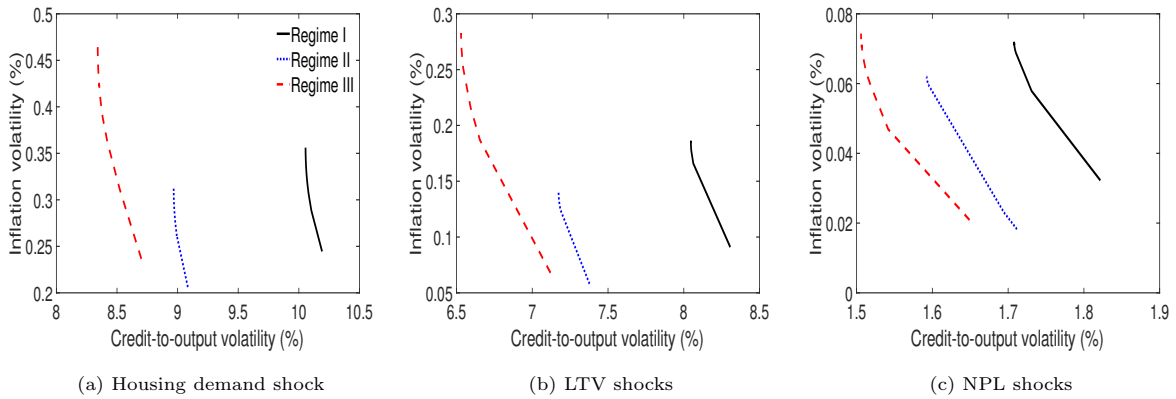

| (a) Housing demand shock | (b) LTV shocks | (c) NPL shocks |

Figure 5: The efficient policy frontiers ($\lambda_{l/y} \in [0, 1]$).

Fig. 6 shows, with the presence of macroprudential policy, the trade-off between the volatilities of output and inflation when the economy faces housing demand, LTV and NPL shocks. The results show that the introduction of macroprudential policy (regime II) shifts the efficiency frontier to the left, implying a more efficient policy outcome in terms of reducing the volatilities of inflation and output relative to the benchmark regime (regime I). This implies that macroprudential policy enhances the effectiveness of monetary policy. When the central bank implements a policy regime III, we see that the frontier shifts further to the left and up. This implies that allowing monetary policy to react to financial imbalances weakens monetary policy's ability to deliver on its primary objective - price stability.
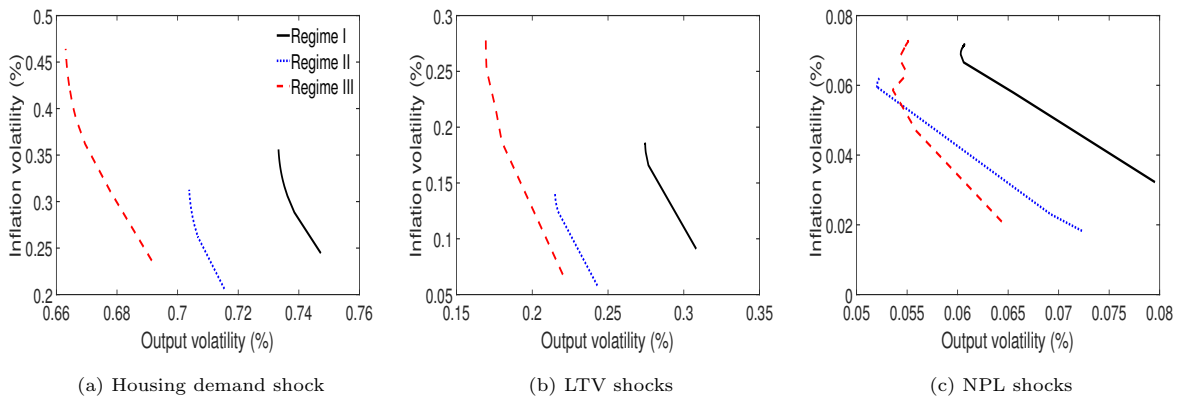

| (a) Housing demand shock | (b) LTV shocks | (c) NPL shocks |

Figure 6: The efficient policy frontiers: inflation vs output ($\lambda_{l/y} \in [0, 1]$).

28

The efficient policy frontier analysis reaffirms the findings in the previous section. A policy regime that combines a standard monetary policy and macroprudential policy enhances both macroeconomic (price) stability and financial stability. This policy regime delivers the maximum attainable financial stability benefits at the lowest cost of price stability. These findings also concur with Rubio and Carrasco-Gallego (2014), in which the authors establish that a policy combination of a standard monetary policy and countercyclical LTV regulation enhances the overall economic stability. In addition, our analysis suggests that a policy regime that combines an augmented monetary policy and macroprudential policy can compromise price stability, consistent with Rubio (2016) and Gelain et al. (2013).

8   Conclusion

This paper investigates the optimal design and the interaction between monetary and macroprudential policies for the South African economy. We find that a simultaneous deployment of monetary and macroprudential policies enhances macroeconomic (price) and financial stability. A policy regime that combines an augmented monetary policy with macroprudential policy delivers the highest welfare gains, but at a much higher cost of price instability than a regime that combines a standard monetary policy with macroprudential policy. An efficient policy frontier analysis shows that a combination of a standard monetary policy and a macroprudential policy is the most efficient policy regime in terms of enhancing both macroeconomic and financial stability.

The policy implication of our findings is that the central bank should be cautious when allowing monetary policy to react to financial conditions. In particular, our analysis suggests that the central bank should not use monetary policy to lean against the wind of credit cycles in an attempt to promote financial stability. Rather the central bank should introduce macroprudential policy instruments (like CcCR, studied here) with a primary objective of financial stability, and let monetary policy focus exclusively on its primary objective of price stability. Such a policy coordination will facilitate a simultaneous pursuit of both macroeconomic (price) and financial stability objectives as documented in Badarau and Popescu (2014) and Cesa-Bianchi and Rebucci (2017).

References

Adrian, T., Liang, N., 2018. Monetary policy, financial conditions, and financial stability. International Journal of Central Banking 14 (1), 73–131.

Agénor, P.-R., Alper, K., da Silva, L. P., 2018. External shocks, financial volatility and reserve requirements in an open economy. Journal of Financial Stability 83, 23–43.

Agénor, P.-R., Alper, K., da Silva, L. P., et al., 2013. Capital regulation, monetary policy and financial stability. International Journal of Central Banking 9 (3), 193–238.

Agénor, P.-R., Pereira da Silva, L., 2017. Cyclically adjusted provisions and financial stability. Journal of International Money and Finance 28, 143–162.

Alpanda, S., Kotzé, K., Woglom, G., 2010. The role of the exchange rate in a New Keynesian DSGE model for the South African economy. South African Journal of Economics 78 (2), 170–191.

An, S., Schorfheide, F., 2007. Bayesian analysis of DSGE models. Econometric Reviews 26 (2-4), 113–172.

Angelini, P., Neri, S., Panetta, F., 2014. The interaction between capital requirements and monetary policy. Journal of Money, Credit and Banking 46 (6), 1073–1112.

Angeloni, I., Faia, E., 2013. Capital regulation and monetary policy with fragile banks. Journal of Monetary Economics 60 (3), 311–324.

Aye, G. C., Balcilar, M., Bosch, A., Gupta, R., 2014. Housing and the business cycle in South Africa. Journal of Policy Modeling 36 (3), 471–491.

Badarau, C., Popescu, A., 2014. Monetary policy and credit cycles: a DSGE analysis. Economic Modelling 42, 301–312.

Bailliu, J., Meh, C., Zhang, Y., 2015. Macroprudential rules and monetary policy when financial frictions matter. Economic Modelling 50 (6), 148–161.

Benes, J., Kumhof, M., 2015. Risky bank lending and countercyclical capital buffers. Journal of Economic Dynamics and Control 58, 58–80.

Bouvatier, V., Lepetit, L., 2012. Provisioning rules and bank lending: a theoretical model. Journal of Financial Stability 8 (1), 25–31.

Calvo, G. A., 1983. Staggered prices in a utility-maximizing framework. Journal of Monetary Economics 12 (3), 383–398.

Cesa-Bianchi, A., Rebucci, A., 2017. Does easing monetary policy increase financial instability? Journal of Financial Stability 30, 111–125.

Curdia, V., Woodford, M., 2010. Credit spreads and monetary policy. Journal of Money, credit and Banking 42 (s1), 3–35.

du Plessis, S., Smit, B., Steinbach, R., 2014. A medium-sized open economy DSGE model of South Africa. Working paper series wp/14/04, South African Reserve Bank.

Funke, M., Kirkby, R., Mihaylovski, P., 2018. House prices and macroprudential policy in an estimated DSGE model of New Zealand. Journal of Macroeconomics 56, 152–171.

Gambacorta, L., Signoretti, F. M., 2014. Should monetary policy lean against the wind?: an analysis based on a DSGE model with banking. Journal of Economic Dynamics and Control 43, 146–174.

Gelain, P., Ilbas, P., 2017. Monetary and macroprudential policies in an estimated model with financial intermediation. Journal of Economic Dynamics and Control 78, 164–189.

Gelain, P., Lansing, K. J., Mendicino, C., 2013. House prices, credit growth, and excess volatility: implications for monetary and macroprudential policy. International Journal of Central Banking 9 (2), 219–276.

Glen, J., Mondragón-Vélez, C., 2011. Business cycle effects on commercial bank loan portfolio performance in developing economies. Review of Development Finance 1 (2), 150–165.

Gourinchas, P.-O., Obstfeld, M., 2012. Stories of the twentieth century for the twenty-first. American Economic Journal: Macroeconomics 4 (1), 226–65.

Guerrieri, L., Iacoviello, M., 2017. Collateral constraints and macroeconomic asymmetries. Journal of Monetary Economics 90 (C), 28–47.

Gupta, R., Sun, X., 2018. Housing market spillovers in South Africa: evidence from an estimated small open economy DSGE model. Empirical Economics, 1–24.

Iacoviello, M., 2005. House prices, borrowing constraints, and monetary policy in the business cycle. American Economic Review 95 (3), 739–764.

Iacoviello, M., 2015. Financial business cycles. Review of Economic Dynamics 18 (1), 140–163.

Iacoviello, M., Minetti, R., 2006. International business cycles with domestic and foreign lenders. Journal of Monetary Economics 53 (8), 2267–2282.

IMF, 2011. Durable financial stability: getting there from here. Global Financial Stability Report April 2011, International Monetary Fund.

Jeanneau, S., 2014. Financial Stability Objectives and Arrangements–What's New? Tech. Rep. BIS Papers 76, Bank for International Settlements.

Jordà, Ò., Schularick, M., Taylor, A. M., 2015. Leveraged bubbles. Journal of Monetary Economics 76, S1–S20.

Kannan, P., Rabanal, P., Scott, A. M., 2012. Monetary and macroprudential policy rules in a model with house price booms. The BE Journal of Macroeconomics 12 (1), 1–44.

Lambertini, L., Mendicino, C., Punzi, M. T., 2013. Leaning against boom–bust cycles in credit and housing prices. Journal of Economic Dynamics and Control 37 (8), 1500–1522.

Liu, G., 2013. Will the SARB always succeed in fighting inflation with contractionary policy? South African Journal of Economics 81 (3), 330–345.

Liu, G., Molise, T., 2019. The effectiveness of the counter-cyclical loan-to-value regulation: Generic versus sector-specific rules. Economic Research Southern Africa, Working Paper 795.

Liu, G., Seeiso, N. E., 2012. Basel II procyclicality: the case of South Africa. Economic Modelling 29 (3), 848–857.

Liu, Z., Wang, P., Zha, T., 2013. Land-price dynamics and macroeconomic fluctuations. Econometrica 81 (3), 1147–1184.

Mallick, S. K., Sousa, R. M., 2013. The real effects of financial stress in the eurozone. International Review of Financial Analysis 30, 1–17.

Mendicino, C., Punzi, M. T., 2014. House prices, capital inflows and macroprudential policy. Journal of Banking & Finance 49, 337–355.

Minetti, R., Peng, T., 2018. Credit policies, macroeconomic stability and welfare: the case of China. Journal of Comparative Economics 1 (46), 35–52.

Ngo, P. V., 2015. Household leverage, housing markets, and macroeconomic fluctuations. Journal of Macroeconomics 44, 191–207.

Quint, D., Rabanal, P., 2014. Monetary and macroprudential policy in an estimated DSGE model of the Euro Area. International Journal of Central Banking 10 (2), 169–236.

Rubio, M., 2016. Short and long-term interest rates and the effectiveness of monetary and macroprudential policies. Journal of Macroeconomics 47, 103–115.

Rubio, M., Carrasco-Gallego, J. A., 2014. Macroprudential and monetary policies: implications for financial stability and welfare. Journal of Banking & Finance 49, 326–336.

Rubio, M., Carrasco-Gallego, J. A., 2016. The new financial regulation in Basel III and monetary policy: A macroprudential approach. Journal of Financial Stability 26, 294–305.

Schmitt-Grohé, S., Uribe, M., 2007. Optimal simple and implementable monetary and fiscal rules. Journal of Monetary Economics 54 (6), 1702–1725.

Schularick, M., Taylor, A. M., 2012. Credit booms gone bust: monetary policy, leverage cycles, and financial crises, 1870-2008. American Economic Review 102 (2), 1029–61.

Smets, F., Wouters, R., 2003. An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area. Journal of the European Economic Association 1 (5), 1123–1175.

South African Reserve Bank, 2018. Financial Stability Review second edition 2018. South African Reserve Bank, Pretoria, South Africa.

Steinbach, M., Mathuloe, P., Smit, B., 2009. An open economy New Keynesian DSGE model of the South African economy. South African Journal of Economics 77 (2), 207–227.

Steinbach, R., du Plessis, S., Smit, B., 2014. Monetary policy and financial shocks in an empirical small open-economy DSGE model. EcoMod2014 7194, EcoMod.

Suh, H., 2014. Dichotomy between macroprudential policy and monetary policy on credit and inflation. Economics Letters 122 (2), 144–149.

Svensson, L. E., 2012. Comment on michael woodford, "inflation targeting and financial stability". Sveriges Riksbank Economic Review 1, 33–40.

Svensson, L. E., 2017. Cost-benefit analysis of leaning against the wind. Journal of Monetary Economics 90, 193–213.

Tayler, W. J., Zilberman, R., 2016. Macroprudential regulation, credit spreads and the role of monetary policy. Journal of Financial Stability 26, 144–158.

Taylor, A. M., 2015. Credit, financial stability, and the macroeconomy. Annual Review of Economics 7 (1), 309–339.

Turdaliev, N., Zhang, Y., 2019. Household debt, macroprudential rules, and monetary policy. Economic Modelling 77, 234–252.

Verona, F., Martins, M. M., Drumond, I., 2017. Financial shocks, financial stability, and optimal taylor rules. Journal of Macroeconomics 54, 187–207.

Zhang, Y., 2019. Household debt, financial intermediation, and monetary policy. Journal of Macroeconomics 59, 230–257.

A   Complete set of equations for the log-linearised model

Variables with a hat denote percent deviations from steady state and those without a time subscript are steady states.

Patient Households

$$\hat{u}_{cs,t} = -\frac{1}{1-\eta_s}\big(\hat{c}_{s,t} - \eta_s\hat{c}_{s,t-1}\big), \tag{A.1}$$

$$E_t(\hat{u}_{cs,t+1} - \hat{u}_{cs,t}) + E_t(\hat{r}_t - \hat{\pi}_{t+1}) = 0, \tag{A.2}$$

$$\hat{q}_t = (1-\beta_s)(\hat{a}_{j,t} - \hat{h}_{s,t}) + \beta_s E_t\hat{u}_{cs,t+1} - \hat{u}_{cs,t} + \beta_s E_t\hat{q}_{t+1}, \tag{A.3}$$

$$\hat{w}_{s,t} = \frac{n_s}{1-n_s}\hat{n}_{s,t} - \hat{u}_{cs,t}, \tag{A.4}$$

$$\frac{c_s}{y}\hat{c}_{s,t} = \frac{wn_s}{y}(\hat{w}_{s,t} + \hat{n}_{s,t}) - \frac{qh_s}{y}(\hat{h}_{s,t} - \hat{h}_{s,t-1}) + \frac{x-1}{x}\hat{y}_t + \frac{1}{x}\hat{x}_t - \frac{d}{y}\Big[\hat{d}_t - \frac{r}{\pi}(\hat{r}_{t-1} - \hat{\pi}_t + \hat{d}_{t-1})\Big]. \tag{A.5}$$

Impatient Households

$$\hat{u}_{cb,t} = -\frac{1}{1-\eta_b}\big(\hat{c}_{b,t} - \eta_b\hat{c}_{b,t-1}\big), \tag{A.6}$$

$$\hat{l}_{b,t} = E_t(\hat{q}_{t+1} + \hat{h}_{b,t} - \hat{r}_{b,t} + \hat{\pi}_{t+1}) + \hat{\gamma}_{b,t}, \tag{A.7}$$

$$\Gamma_{b1}E_t(\hat{u}_{cb,t+1} - \hat{u}_{cb,t} + \hat{r}_{b,t} - \hat{\pi}_{t+1}) = \beta_b\zeta_b(1-\vartheta_b)\frac{r_b}{\pi}\hat{\zeta}_{b,t+1} - (1-\Gamma_{b1})(\hat{\lambda}_{b,t} - \hat{u}_{cb,t}), \tag{A.8}$$

$$\hat{q}_t = (1-\Gamma_{b2})[\hat{a}_{j,t}-\hat{h}_{b,t}-\hat{u}_{cb,t}]+\Gamma_{b2}\hat{q}_{t+1}+(\Gamma_{b2}-\beta_b)[\hat{\lambda}_{b,t}-\hat{u}_{cb,t}+\hat{\gamma}_{b,t}-\hat{r}_{b,t}+\hat{\pi}_{t+1}]+\beta_b(\hat{u}_{cb,t+1}-\hat{u}_{cb,t}), \tag{A.9}$$

$$\hat{w}_{b,t} = \frac{n_b}{1-n_b}\hat{n}_{b,t} - \hat{u}_{cb,t}, \tag{A.10}$$

$$\hat{\zeta}_{b,t} = -\chi_{\zeta b}(\hat{y}_t - \hat{y}_{t-1}) + \hat{\varepsilon}_{b,t}, \tag{A.11}$$

$$\frac{c_b}{y}\hat{c}_{b,t} = \frac{wn_b}{y}(\hat{w}_{b,t}+\hat{n}_{b,t}) - \frac{qh_b}{y}(\hat{h}_{b,t}-\hat{h}_{b,t-1}) + \frac{l_b}{y}\Big[\hat{l}_{b,t}-\frac{\Gamma_{b1}}{\beta_b}(\hat{l}_{b,t-1}+\hat{r}_{b,t-1}-\hat{\pi}_t)+\zeta_b(1-\vartheta_b)\frac{r_b}{\pi}\hat{\zeta}_{b,t}\Big], \tag{A.12}$$

where, $\Gamma_{b1} = \beta_b\Big[1 - \zeta_b(1-\vartheta_b)\Big]\frac{r_b}{\pi}$ and $\Gamma_{b2} = \beta_b + m_b\Big[\frac{\pi}{r_b} - \beta_b\Big(1 - \zeta_b(1-\vartheta_b)\Big)\Big]$.

Entrepreneurs

$$\hat{u}_{ce,t} = -\frac{1}{1-\eta_e}\big(\hat{c}_{e,t} - \eta_e\hat{c}_{e,t-1}\big), \tag{A.13}$$

$$\hat{l}_{e,t} = E_t(\hat{q}_{t+1} - \hat{r}_{e,t+1} + \hat{\pi}_{t+1} + \hat{h}_{e,t}) + \hat{\gamma}_{e,t}, \tag{A.14}$$

$$\Gamma_{e1}E_t(\hat{u}_{ce,t+1} - \hat{u}_{ce,t} + \hat{r}_{e,t+1} - \hat{\pi}_{t+1}) = \beta_e\zeta_e(1-\vartheta_e)\frac{r_e}{\pi}\hat{\zeta}_{e,t+1} - (1-\Gamma_{e1})(\hat{\lambda}_{e,t} - \hat{u}_{ce,t}), \tag{A.15}$$

$$\hat{q}_t = (1-\Gamma_{e2})(\hat{y}_{t+1} - \hat{x}_{t+1} - \hat{h}_{e,t}) + \Gamma_{e2}\hat{q}_{t+1} + (\Gamma_{e2}-\beta_e)(\hat{\lambda}_{e,t} - \hat{u}_{ce,t} - \hat{r}_{e,t+1} + \hat{\pi}_{t+1} + \hat{\gamma}_{e,t}) +$$
$$(1+\beta_e - \Gamma_{e2})(\hat{u}_{ce,t+1} - \hat{u}_{ce,t}), \tag{A.16}$$

$$\hat{w}_{s,t} = \hat{y}_t - \hat{x}_t - \hat{n}_{s,t}, \tag{A.17}$$

$$\hat{w}_{b,t} = \hat{y}_t - \hat{x}_t - \hat{n}_{b,t}, \tag{A.18}$$

$$\hat{y}_t = \hat{z}_t + \nu\hat{h}_{e,t-1} + (1-\nu)(1-\sigma)\hat{n}_{s,t} + \sigma(1-\nu)\hat{n}_{b,t}, \tag{A.19}$$

$$\hat{\zeta}_{e,t} = -\chi_{\zeta e}(\hat{y}_t - \hat{y}_{t-1}) + \hat{\varepsilon}_{e,t}, \tag{A.20}$$

$$\frac{c_e}{y}\hat{c}_{e,t} = \frac{l_e}{y}\left[\hat{l}_{e,t} - \frac{r_e}{\pi}[1 - \zeta_e(1-\vartheta_e)](\hat{l}_{e,t-1} + \hat{r}_{e,t} - \hat{\pi}_t) + \zeta_e(1-\vartheta_e)\frac{r_e}{\pi}\hat{\zeta}_{e,t}\right] - \frac{qh_e}{y}(\hat{h}_{e,t} - \hat{h}_{e,t-1})$$

$$+ \frac{1}{x}(\hat{y}_t - \hat{x}_t) - \frac{wn_s}{y}(\hat{w}_{s,t} + \hat{n}_{s,t}) - \frac{wn_b}{y}(\hat{w}_{b,t} + \hat{n}_{b,t}) \tag{A.21}$$

where, $\Gamma_{e1} = \beta_e\left[1 - \zeta_e(1-\vartheta_e)\right]\frac{r_e}{\pi}$ and $\Gamma_{e2} = \beta_e + m_e\left[\frac{\pi}{r_e} - \beta_e\left(1 - \zeta_e(1-\vartheta_e)\right)\right]$.

The bank

$$\hat{u}_{cf,t} = -\frac{1}{1-\eta_f}(\hat{c}_{f,t} - \eta_f\hat{c}_{f,t-1}), \tag{A.22}$$

$$\beta_f\frac{r}{\pi}E_t(\hat{r}_t - \hat{\pi}_{t+1}) = -\beta_f\frac{r}{\pi}E_t(\hat{u}_{cf,t+1} - \hat{u}_{cf,t}) - \lambda_{fss}(\hat{\lambda}_{f,t} - \hat{u}_{cf,t}), \tag{A.23}$$

$$\Gamma_{fb2}(\hat{r}_{b,t} - \hat{\pi}_{t+1}) = \left(\beta_f\frac{r_b}{\pi} - \Gamma_{fb2}\right)\hat{\zeta}_{b,t+1} - (1 - w_b\kappa)\lambda_{fss}\Gamma_{fb3}(\hat{\lambda}_{f,t} - \hat{u}_{cf,t}) + w_b\kappa\lambda_{fss}\Gamma_{fb3}\hat{\kappa}_t$$

$$- \Gamma_{fb1}(\hat{u}_{cf,t+1} - \hat{u}_{cf,t}) + \phi_{bf}(\hat{l}_{b,t} - \hat{l}_{b,t-1}), \tag{A.24}$$

$$\Gamma_{fe2}(\hat{r}_{e,t+1} - \hat{\pi}_{t+1}) = \left(\beta_f\frac{r_e}{\pi} - \Gamma_{fe2}\right)\hat{\zeta}_{e,t+1} - (1 - w_e\kappa)\lambda_{fss}\Gamma_{fe3}(\hat{\lambda}_{f,t} - \hat{u}_{cf,t}) + w_e\kappa\lambda_{fss}\Gamma_{fe3}\hat{\kappa}_t$$

$$- \Gamma_{fe1}(\hat{u}_{cf,t+1} - \hat{u}_{cf,t}) + \phi_{ef}(\hat{l}_{e,t} - \hat{l}_{e,t-1}), \tag{A.25}$$

$$\frac{d}{y}\hat{d}_t = (1 - w_b\kappa)\frac{l_b}{y}\left[\Gamma_{fb3}\hat{l}_{b,t} - \frac{r_b}{\pi}\zeta_b\left(\hat{r}_{b,t} - \hat{\pi}_{t+1} + \hat{\zeta}_{b,t+1}\right)\right] - w_b\kappa\Gamma_{fb3}\frac{l_b}{y}\hat{\kappa}_t - w_e\kappa\Gamma_{fe3}\frac{l_e}{y}\hat{\kappa}_t$$

$$+ (1 - w_e\kappa)\frac{l_e}{y}\left[\Gamma_{fe3}\hat{l}_{e,t} - \frac{r_e}{\pi}\zeta_e\left(\hat{r}_{e,t+1} - \hat{\pi}_{t+1} + \hat{\zeta}_{e,t+1}\right)\right], \tag{A.26}$$

where, $\Gamma_{fb1} = \beta_f\frac{r_b}{\pi}(1 - \zeta_b)$, $\Gamma_{fb2} = \Gamma_{fb1} - (1 - w_b\kappa)\lambda_{fss}\frac{r_b}{\pi}\zeta_b$, $\Gamma_{fb3} = 1 - \frac{r_b}{\pi}\zeta_b$, $\Gamma_{fe1} = \beta_f\frac{r_e}{\pi}(1 - \zeta_e)$, $\Gamma_{fe2} = \Gamma_{fe1} - (1 - w_e\kappa)\lambda_{fss}\frac{r_e}{\pi}\zeta_e$ and $\Gamma_{fe3} = 1 - \frac{r_e}{\pi}\zeta_e$.

Aggregate consumption and market clearing conditions

$$\frac{c}{y}\hat{c}_t = \frac{c_s}{y}\hat{c}_{s,t} + \frac{c_b}{y}\hat{c}_{b,t} + \frac{c_e}{y}\hat{c}_{e,t} + \frac{c_b}{y}\hat{c}_{f,t}, \tag{A.27}$$

$$\frac{h_s}{y}\hat{h}_{s,t} + \frac{h_b}{y}\hat{h}_{b,t} + \frac{h_e}{y}\hat{h}_{e,t} = 0, \tag{A.28}$$

$$\frac{l}{y}\hat{l}_t = \frac{l_b}{y}\hat{l}_{b,t} + \frac{l_e}{y}\hat{l}_{e,t}. \tag{A.29}$$

Monetary policy rule, inflation dynamics and shock processes

$$\hat{r}_t = \phi_r\hat{r}_{t-1} + (1 - \phi_r)[\phi_\pi\hat{\pi}_t + \phi_y\Delta\hat{y}_t] + \xi_{r,t}, \tag{A.30}$$

$$\hat{\pi}_t = \frac{\iota_p}{1 + \iota_p\beta_s}\hat{\pi}_{t-1} + \frac{\beta_s}{1 + \iota_p\beta_s}E_t\hat{\pi}_{t+1} - \frac{(1-\theta)(1-\beta_s\theta)}{(1+\iota_p\beta_s)\theta}\hat{x}_t + \xi_{\pi,t}, \tag{A.31}$$

$$\hat{a}_{j,t} = \rho_j\hat{a}_{j,t-1} + \xi_{j,t}, \tag{A.32}$$

$$\hat{z}_t = \rho_z\hat{z}_{t-1} + \xi_{z,t}, \tag{A.33}$$

$$\hat{\gamma}_{b,t} = \rho_{\gamma b}\hat{\gamma}_{b,t-1} + \xi_{\gamma b,t}, \tag{A.34}$$

$$\hat{\gamma}_{e,t} = \rho_{\gamma e}\hat{\gamma}_{e,t-1} + \xi_{\gamma e,t}, \tag{A.35}$$

$$\hat{\varepsilon}_{b,t} = \rho_{\varepsilon b}\hat{\varepsilon}_{b,t-1} + \xi_{\varepsilon b,t}, \tag{A.36}$$

$$\hat{\varepsilon}_{e,t} = \rho_{\varepsilon e}\hat{\varepsilon}_{e,t-1} + \xi_{\varepsilon e,t}, \tag{A.37}$$

where $\xi_{i,t} \sim i.i.d.N(0, \sigma_i^2)$ is the white noise process, normally distributed with mean zero and variance σ_i^2, $\forall i = \{r, \pi, j, z, \gamma b, \gamma e, \varepsilon b, \varepsilon e\}$.

Measurement equation

The measurement equation describes how the empirical data (actual times series) is matched to the corresponding model variables:

$$
\begin{bmatrix}
\Delta log(Y_t^{obs}) - \bar{\gamma}_y \\
\Delta log(q_t^{obs}) - \bar{\gamma}_q \\
\Delta log(L_{b,t}^{obs}) - \bar{\gamma}_{lb} \\
\Delta log(L_{e,t}^{obs}) - \bar{\gamma}_{le} \\
log(\Pi_t^{obs}) - \bar{\gamma}_\pi \\
log(R_t^{obs}) - \bar{\gamma}_r \\
log(\zeta_{b,t}^{obs}) - \bar{\gamma}_{\zeta_b} \\
log(\zeta_{e,t}^{obs}) - \bar{\gamma}_{\zeta_e}
\end{bmatrix}
=
\begin{bmatrix}
\hat{y}_t - \hat{y}_{t-1} \\
\hat{q}_t - \hat{q}_{t-1} \\
\hat{l}_{b,t} - \hat{l}_{b,t-1} \\
\hat{l}_{e,t} - \hat{l}_{e,t-1} \\
\hat{\pi}_t \\
\hat{r}_t \\
\hat{\zeta}_{b,t} \\
\hat{\zeta}_{e,t}
\end{bmatrix}
+
\begin{bmatrix}
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
\xi_{\varepsilon_b,t}^{me} \\
\xi_{\varepsilon_e,t}^{me}
\end{bmatrix},
\tag{A.38}
$$

where Δ is the temporal difference operator and $\bar{\gamma}_i$ is the sample mean of the respective transformed variables. $\xi_{\varepsilon_b,t}^{me}$ and $\xi_{\varepsilon_e,t}^{me}$ are measurement errors to allow for the fact that the data on household and entrepreneur NPLs is an approximation of the actual underlying series.

B   Data and sources

Most of the data are obtained from the South African Reserve Bank database. The exceptions are house price data from ABSA bank, interest rate data from the IMF's International Financial Statistics database, and population data from the World Bank database.

1. **Output** (y_t): real GDP, quarterly, seasonally adjusted at annual rate.

2. **Household loans** $(L_{b,t})$: Total credit to households (sum of mortgage credit, instalment sales credit, leasing finance, overdrafts, credit cards and other loans and advances), not seasonally adjusted. These data are deflated by the GDP deflator to get the real counterpart.

3. **Entrepreneur loans** $(L_{e,t})$: Total credit to non-financial corporates (sum of mortgage credit, instalment sales credit, leasing finance, overdrafts, credit cards, other loans and advances and investments and bills), not seasonally adjusted. These data are deflated by the GDP deflator to get the real counterpart.

4. **House prices** (q_t): Middle-segment nominal house price index (seasonally adjusted) obtained from ABSA bank. This index is available monthly, and is converted to quarterly values based on a three-month average. The use of the entire middle-segment house price data set is justified on the basis that these data are regarded as the most representative of the general house price level prevailing in the South African economy (Aye et al., 2014, 476). These data are deflated by the GDP deflator to get the real counterpart.

5. **Inflation** (π_t): Inflation is measured by quarterly changes in the GDP deflator.

6. **Short-term nominal interest rate** (R_t): 90-day treasury bill rate as a proxy for policy rate. Since nominal interest rate data are provided in an annualised form, we transformed these data into quarterly data by dividing the original data by 400 to match the frequency of the model. These data are obtained from the IMF's International Financial Statistics database.

7. **Population**: The population aged between 15 and 64. Data on population are obtained from World Bank database and available at annual frequency. To construct quarterly population data, we assume that the population increases at a linear rate throughout the year.

8. **Ratios of household and corporate NPLs (non-performing loans)** $(\zeta_{b,t}$ and $\zeta_{e,t})$: Impaired advances (advances in respect of which the bank has raised a specific impairment). These data are available only at aggregate level (total NPLs). To construct data on household NPLs, we multiply the ratio of household loans to total loans by total NPLs. We then divide the resulting household NPLs by household loans to get data on the ratio of household NPLs $(\zeta_{b,t})$. We do the same to construct data on the ratio of corporate NPLs $(\zeta_{e,t})$.