The optimal monetary and macroprudential policies in an estimated DSGE Model for South Africa

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Abstract

This paper studies the optimal design and the effectiveness of monetary and macroprudential policies in promoting financial stability and macroeconomic stability for the South African economy. We develop a New Keynesian dynamic stochastic general equilibrium (DSGE) model featuring a housing market, a banking sector and the role for macroprudential and monetary policies. We estimate the model with Bayesian techniques using the South African data over the sample period 2000Q1–2016Q4. We find that a simultaneous deployment of optimal monetary and macroprudential policies attenuates fluctuations in the housing market, the credit market and the real sector. Efficient policy frontier analysis suggests that the optimal combination of a standard monetary policy and macroprudential policy unambiguously enhances both macroeconomic stability and financial stability. The policy regime that combines an augmented monetary policy with macroprudential policy is superior in enhancing output and financial stability, but this comes at the cost of compromising price stability. Our findings suggest that monetary policy should focus solely on its primary objective of macroeconomic (price) stability and let macroprudential policy facilitates financial stability on its own.

Keywords: Monetary policy, Macroprudential policy, Financial stability, Financial shocks, DSGE models.
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1 Introduction

The 2007/08 financial crisis highlighted the importance of financial stability for the overall stability of the economy. It became evident that price stability and financial safety and soundness of individual financial institutions alone are necessary, but not sufficient, conditions for the overall stability of the economy. As a result, consensus emerges among the world leaders to adopt macroprudential approach to financial regulation within the overall framework of macroprudential policy. The main objective of macroprudential policy is to mitigate the buildup of financial systemic risk and reduce the macroeconomic cost of financial crises with the ultimate goal of financial stability. These developments have also led many central banks around the world, including South African Reserve Bank, to expand their mandate to include financial stability objective in addition to price stability objective.[1]

The incorporation of macroprudential policy function into the central bank policy framework raises a question regarding the coordination between monetary and macroprudential policies. This stems from the observation that the two policies do not affect economic conditions in isolation; the impact of either of the two policies has a bearing on the other. While macroprudential policy provides a channel through which authorities promote financial stability, this policy does not affect economic conditions in a vacuum (isolation), without a bearing on other macroeconomic policies especially monetary policy. Through its effect on credit growth, macroprudential policy affects monetary conditions and hence the conduct of monetary policy. Similarly, monetary policy affects credit conditions through its effect on credit growth and thus has implications for macroprudential policy. This implies that the twin goals of monetary and macroprudential policies are mutually dependent. Their interaction extends from the consequences that failing to achieve either one has for the difficulty of achieving the other. Despite these considerations, little is known on how monetary and macroprudential policies interacts as their ultimate goals have implication for the overall stability of the economy.

Specifically, the literature is yet to find a common ground on how monetary and macroprudential policies should be jointly implemented to facilitate a simultaneous pursuit of macroeconomic and financial stability. One strand of the literature considers a standard monetary policy that reacts to inflation and output and examine its interaction with macroprudential policy (e.g., Angelini et al.; 2014, Quint and Rabanal; 2014, Rubio and Carrasco-Gallego; 2014, 2016). The general conclusion in these studies is that a combination of a standard monetary policy and macroprudential policy is effective in enhancing financial and macroeconomic stability, especially when the economy faces shocks emanating from housing market and financial sector. Nonetheless, within a general equilibrium framework featuring endogenous credit risk, Tayler and Zilberman (2016) establish that a policy regime that combines a strong anti-inflation monetary policy with an aggressive macroprudential policy (that reacts to credit risk) is also effective in enhancing financial and macroeconomic stability in the case of technology (non-financial) shock. In a nutshell, these studies suggest that a policy regime in which monetary policy is exclusively assigned macroeconomic (price) stability objective while macroprudential policy is exclusively assigned financial

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

stability objective facilitates a simultaneous pursuit of both macroeconomic and financial stability. This is also consistent with studies such as Svensson (2012), Gelain et al. (2013), Suh (2014), Svensson (2017) and Turdaliev and Zhang (2019), in which the authors advocate for a separation of policy responsibilities for monetary policy and macroprudential policy.

The other strand of the literature considers a monetary policy that also reacts to financial variables (either credit, interest rate spread or asset prices) in addition to inflation and output (an augmented monetary policy) and examine 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 establish that an augmented monetary policy enhances macroeconomic and financial stability and complementing this policy with macroprudential policy enhances the stabilisation benefits more. These studies suggest that a simultaneous pursuit of macroeconomic (price) and financial stability is better achieved by a policy regime that combines an augmented monetary policy and macroprudential policy. They claim that monetary policy should also promote financial stability in addition to macroeconomic (price) stability consistent with Curdia and Woodford (2010), Gambacorta and Signoretti (2014), Verona et al. (2017) and Adrian and Liang (2018). These studies document that there are some gains from allowing monetary policy to react to emerging financial imbalances and promote financial stability. The argument is that monetary policy should consider a broader objective of an overall economic stability rather than a narrow focus on price stability. In contrast, Benes and Kumhof (2015), Tayler and Zilberman (2016) and Turdaliev and Zhang (2019) establish that a monetary policy that reacts to financial imbalances is welfare detrimental irrespective of whether is used in conjunction with macroprudential policy and the shock hitting the economy.

The paper is therefore an attempt to contribute to the literature by examining the interaction between monetary and macroprudential policies within a framework in which heterogeneous borrowers (households and non-financial corporates) from distinct sectors of the credit market co-exist. The majority of the literature examines the interaction between the two policies within a framework in which there is one type of a borrower; either a household borrower or a non-financial corporate borrower. We argue that policy analysis based on this kind of a framework is likely to miss some of the key transmission channels and trade-offs within the economy and therefore less informative for the policymakers. One of the few studies which examine the interaction between monetary and macroprudential policies within a framework in which household and non-financial corporate borrowers co-exist is Angelini et al. (2014). In contrast to Angelini et al. (2014), we also consider a monetary policy that reacts to emerging financial imbalances and study its interaction with macroprudential policy. Furthermore, our analysis considers a broad range of financial shocks. Our approach is also relevant in the context of South Africa because bank lending is more or less equally distributed between households and corporates.[2] The analysis using a framework in which heterogeneous borrowers co-exist 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. This kind of analysis is missing in the literature.

[2]South African credit market data suggests that the average ratio of household loans to total bank loans is 52% while that of corporate loans to total bank loans is 48% over the period 2000Q1–2016Q4.

In addition, to the best of our knowledge, this study is the first of its kind to investigate the interaction between monetary and macroprudential policies in South African context. Majority of the literature examine the interaction between monetary and macroprudential policies in the context of developed economies and little is done in the context of emerging market economies such as South Africa.[3] We argue that conclusions and policy recommendations derived from these studies cannot be considered as applicable to emerging market economies, such as South Africa.

The main objective of the paper is to study the optimal design and the effectiveness of a simultaneous deployment of monetary and macroprudential policies in enhancing financial and macroeconomic stability. We measure macroeconomic stability in terms of volatility of inflation and output, and financial stability in terms of 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 (i.e., capital requirement ratio is constant). The benchmark regime (Policiy I) is exemplified by a standard monetary policy rule that relates the policy rate to inflation and output growth. The first alternative policy regime (Policy II) is a combination of a standard monetary policy rule and macroprudential policy rule. Macroprudential policy is exemplified by a countercyclical capital requirement (CcCR) rule that relates bank capital requirement ratio to deviations of credit-to-output ratio from its steady state in line with Basel III countercyclical capital buffers. The second alternative policy regime (Policy III) is a combination of an augmented monetary policy rule and CcCR rule. An augmented monetary policy rule relates the policy rate to credit growth in addition to inflation and output growth. In this regard, we also investigate whether monetary policy should also promote financial stability in addition to its primary objective of macroeconomic (price) stability.

To conduct our analysis, we develop a New Keynesian dynamic stochastic general equilibrium (DSGE) model which features financial frictions, a housing market, a stylized banking sector and the role for monetary and macroprudential policies. To a modelling framework of Iacoviello (2015), we first embed price stickiness in the model and this permits us to study the stabilisation role of monetary policy. Second, in line with Bouvatier and Lepetit (2012) we introduce endogenous loan losses in the model by assuming that a proportion of loans (borrowed from the previous period) is not repaid in the end. 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. We estimate the model using the South African data over the sample period 2000Q1–2016Q4 with the aid of Bayesian methods.

Based on the estimated model, we first study the optimal combination of monetary and macroprudential policy rules that minimises the policy loss function described in terms of a weighted sum of

[3] A non-exhaustive list includes 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), Turdaliev and Zhang (2019). Among the few studies that examine the interaction between monetary and macroprudential policies in the context of developing economies include Agénor et al. (2013).

volatility of inflation, output, credit-to-output ratio and house prices.[4] We find that, in the presence of financial and macroeconomic stability objectives, the optimal monetary policy rule requires a lower response to inflation and a higher response to output compared to the estimated responses under the benchmark regime. The optimal macroprudential policy rule requires the authority to adjust capital requirement ratio proportionately to deviations of credit-to-output ratio from steady state, irrespective of whether it is jointly deployed with a standard monetary policy rule or an augmented monetary policy rule. Although it is optimal for monetary policy to respond to credit growth, this policy has a potential to destabilise inflation. We also find that a policy regime that combines an augmented monetary policy rule with a CcCR rule (Policy III) delivers the highest welfare gains, but at a much larger cost of increasing inflation volatility in comparison with a policy regime that combines a standard monetary policy rule with a CcCR rule (Policy II).

Using the optimal policy rules, we then compare the behaviour of the model under the three policy regimes following housing demand shock, loan-to-value (LTV) shocks and non-performing loan (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. Specifically, the introduction of macroprudential policy rule limits the bank's ability to take on leverage and supply credit during periods of economic expansion, driven by a positive housing demand shock or LTV shock. In economic contraction, driven by a negative NPL shock, it mitigates rapid deleverage by the bank and facilitates credit supply (enhance the bank's ability to provide loans). In this way, the CcCR regulation mitigates amplification effects of the bank capital constraint on the housing market and the real sector. The results also show that Policy III offers larger attenuation benefits compared to Policy II, but at the expense of price instability. Specifically, our analysis shows that the authority faces a trade-off between price and financial stability objectives when monetary policy also takes into account financial stability mandate and allows the policy rate to respond to credit growth.

Lastly, we perform a policy frontier analysis to assess the efficiency of a simultaneously deployment of monetary and macroprudential policies under the two alternative policy regimes. We show that the introduction of macroprudential policy improves the standard trade-off between output and inflation stabilisation and the trade-off between financial (credit-to-output ratio) and inflation stabilisation. In particular, we find that Policy II is the most efficient policy regime in terms of enhancing both financial stability and macroeconomic stability. Policy III is superior in terms of enhancing output and financial (credit-to-output ratio) stability, but this comes at the cost of destabilising inflation. That is, Policy III is the least efficient policy regime to deliver price stability. In particular, our analysis highlights potential costs of a monetary policy that also reacts to financial conditions. While this policy seems attractive from financial stability point of view, it has a potential to compromise price stability and threaten credibility of monetary policy. Our results therefore casts doubts on the desirability of a monetary policy that accounts for financial stability objective.

The rest of the paper is organised as follows. Section 2 describes the model and Section 3 discusses the

[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.

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. The comparison analysis encompasses three dimensions: welfare loss analysis from stabilisation point of view, model dynamics and efficient policy frontiers. Section 6 presents the results of optimal simple rules conditional on the estimated monetary policy rule and Section 7 concludes.

2 The model

We consider a closed economy New Keynesian dynamic stochastic general equilibrium (DSGE) model.[5] The model features financial frictions, real and nominal rigidities, a housing market, a stylized banking sector and the role for monetary and macroprudential policies. To the workhorse of Iacoviello (2015), we introduce nominal (price) rigidity and incorporate the role for monetary and macroprudential policies. For simplicity, we allow wages to be flexible in the model.

The model economy is populated by two types of households (patient and impatient), entrepreneurs, retailers, the bank and the central bank (the authority). The two types of households work and consume both final goods (consumption goods) and housing services. In equilibrium, patient households are savers while impatient households are borrowers. Entrepreneurs produce homogeneous intermediate goods using households' labour and housing as inputs. They also consume consumption goods and borrow from the bank. The two types of borrowers (impatient households and entrepreneurs) face borrowing constraint, which tie 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 goods (consumption goods).

The main role of the bank is to mediate funds between savers (patient households) and borrowers (impatient households and entrepreneurs) in the economy. The bank is also subject to capital requirement constraint. While the constraint limits the bank's ability to provide loans to borrowers, it also constrains the bank on how much it can take on as deposits (borrow) from patient households. The central bank (authority) implements monetary and macroprudential policies in order to safeguard macroeconomic stability and financial stability. Monetary policy is represented by a Taylor-type rule that relates the policy rate to inflation and output growth. Macroprudential policy is represented by a rule that relates bank capital requirement ratio to deviation of credit-to-output ratio from its steady state in line with Basel III counter-cyclical capital buffers.

[5]We consider a closed economy model because the activities of the South African credit market are largely confined to the domestic economy and the interest in this paper is on policies aimed at dampening fluctuations in the credit market and the associate spillovers to the housing market and the real sector. The South African banking sector data suggests that the domestic banking sector has a relatively low exposure to foreign currency. The average ratio of foreign currency deposits to total liabilities is approximately 4.6 percent while the ratio of foreign currency loans to total assets is approximately 5.0 percent over the period 2008Q1–2016Q4 as per the South African Reserve Bank's BA900 returns. Furthermore, the South African households' and non-financial corporates' borrowings are funded mainly by domestic sources (mainly, commercial banks). Data on domestic non-financial corporates' debt suggests that foreign-denominated debt is negligible at approximately 5.0 percent of total borrowing by non-financial corporate (SARB, 2018).

2.1 Patient Households (Savers)

The representative patient household maximises the expected discounted lifetime utility:

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

where E_0 and $\beta_s \in (0,1)$ are the expectation operator and the household's subjective discount factor, respectively. $C_{s,t}$ is consumption, $H_{s,t}$ is housing stock and $N_{s,t}$ is supply of labour (hours of work).[6] 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:

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

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 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 (retail firms). 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 on one-period risk-free deposit, where R_t is the nominal deposit rate which is equals 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 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.

[6] 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.

2.2 Impatient Households (Borrowers)

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

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

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 accrues 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 non-performing loans (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 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 (lender), the increase in the fraction of NPLs increases loses on the bank's loan portfolio and thus reduces the bank's wealth (income). The same variable appears in the budget constraint of the bank, 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).[7] We argue that NPLs (loan defaults) are symptoms (manifestations) of a distress elsewhere in the economy, such a deteriorating economic conditions which lead to a fall in borrowers' ability to repay loans. This modification also allows us to mimic a real world setting and generates 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 $\sigma^2_{\varepsilon b}$. That is, $\xi_{\varepsilon b,t} \sim i.i.d.N(0, \sigma^2_{\varepsilon b})$. Following Zhang (2019), we assume that in an event of a default the household incurs indirect cost in the form of a bad repayment record that results to low credit score. To capture the cost associated with credit default, we introduce $\vartheta_b \in [0,1]$ which is a fraction of wealth transfer that the household must use to pay for the cost related to the credit default.

The household also faces the following borrowing constraint that limits the amount of borrowing to

[7] 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.

a fraction m_b of the expected value of housing:[8].

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

$m_b \in (0,1)$ is the loan-to-value (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 according to the following:

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

where $\rho_{\gamma b}$ is a parameter governing the persistence of the shock. $\xi_{\gamma b,t} \sim i.i.d.N(0,\sigma^2_{\gamma b})$ is the white noise process, normally distributed with mean zero and variance $\sigma^2_{\gamma b}$. 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).[9]

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:

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

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

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

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 tomorrow 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) highlight that this form of dividend smoothing is essential for the model to adequately explain the dynamics between asset prices and real variables.

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

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

In each period, the representative entrepreneur, z, produces intermediate goods, $Y_t(z)$, using the patient and impatient household 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). 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 budget constraint of the entrepreneur is given by:[10]

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

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 accrues a real gross interest rates, $R_{e,t}/\pi_t$. $\zeta_{e,t}$ is a fraction of entrepreneur NPLs which captures partial defaults by the entrepreneur on the loan contract, as in the case of the impatient household. ϑ_e is a fraction of 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 according to the following:

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

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

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

follows:

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

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

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

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

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 Retail sector

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 maximization yields the demand for good k as:[11]

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

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, we assume that the retailers operate in a monopolistically competitive environment and set prices in a staggered manner following Calvo (1983). In each period, each retailer gets the opportunity to adjust prices to a new level with a probability $(1-\theta)$. 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 $\tilde{Y}_{t+i}(k) = (\tilde{P}_t(k)/P_{t+i})^{-\epsilon} Y_{t+i}$. 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 $X = \epsilon/(\epsilon-1)$.

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

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-linearizing 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, $\xi_{\pi,t} \sim i.i.d.N(0, \sigma_\pi^2)$.[12]

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:

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

where D_t is the 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 non-performing loans, respectively. For the bank, these represent loan losses which the bank incurs when the impatient households and the entrepreneurs default on their loan contracts.

In addition to the budget constraint, the bank faces capital requirement constraint. In line with 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 $BK_t = L_t - E_t\zeta_{t+1} - D_t$.[13] The capital requirement constraint is given by:

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

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

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

where $\kappa \in (0,1)$ is capital requirement ratio (CRR) and $L_t = L_{b,t} + L_{e,t}$ is the total loans. $E_t\zeta_{t+1}$ represents allowance for the expected loan losses. w_b and w_e are risk weights on household and entrepreneur loans, respectively. These parameters capture different degree 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 off 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:

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

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

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

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

2.6 Monetary policy

Analogous to Steinbach et al. (2009) and Alpanda et al. (2010), monetary policy is exemplified by a standard Taylor-type rule with interest rate smoothing as follows:[14]

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

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, $\xi_{r,t} \sim i.i.d.N(0,\sigma_r^2)$.

[14]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.

2.7 Market clearing conditions and equilibrium

The aggregate resource constraint is obtained by adding together 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, total supply of loans equals demand by impatient households and entrepreneurs:

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

3 Estimation

We estimate the model for the South African economy using a Bayesian technique as discussed in An and Schorfheide (2007). We use Dynare (version 4.5.7) to estimate the model.[15] In what follows, we briefly describe the data and present the calibrated parameters, the priors and the estimation results.

3.1 Data

We use the South African quarterly data over the sample period 2000Q1 - 2016Q4, which coincides with the inflation targeting regime of the South African Reserve Bank. The model allows for a total of eight shocks. In line with the standard practice in the DSGE literature, we use as many shocks as the number of observable variables. 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, the ratio of household non-performing loans (NPLs) to total household loans and the ratio of corporate NPLs to total corporate loans. In Appendix B, we present a more detailed description of the data. Prior to empirical analysis, we detrend the logarithm of real variables by taking the first-difference of each variable and subtract the corresponding sample mean. Inflation, interest rate, ratios of household NPLs and corporate NPLs are demeaned. Most of the data is obtained from the South African Reserve Bank database, except for house prices, interest rate and population data. House prices data is obtained from ABSA bank (one of the leading banks in South Africa) while interest rate and population data are obtained from the International Monetary Fund International Financial Statistics and World Bank databases, respectively. The transformed data are plotted in Fig. 1.

[15]Dynare a software platform for solving and estimating dynamic stochastic general equilibrium (DSGE) models (http://www.dynare.org/).

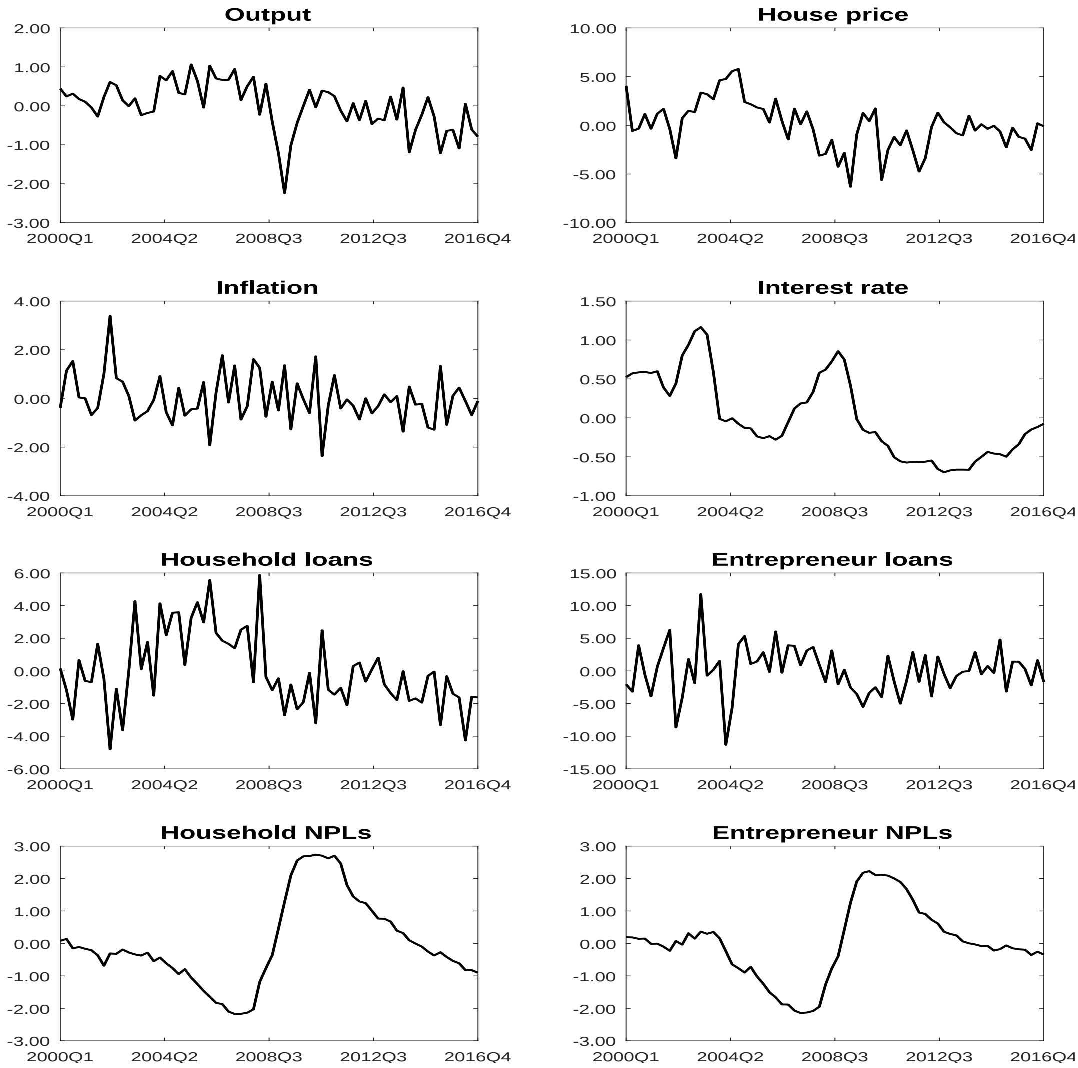


Figure 1: Data used in estimation. Note: Output (GDP), house prices, household loans and entrepreneur (corporate) loans are demeaned percentage growth rates. Inflation rate, interest rate, ratios of household and entrepreneur (corporate) NPLs are in percentage deviations from their respective sample means.

3.2 Calibration

As is standard in Bayesian estimation of DSGE models, we first calibrate a subset of parameters for which data does not provide sufficient information for their estimation. This is because of the difficulties in identifying these parameters based on the observable data set. To calibrate these parameters, we use South African real data over the period 2000Q1 - 2016Q4 to match steady state conditions of the model while others are borrowed from the literature. These parameters are presented in Table 1.

The discount factor for the patient household is set at $\beta_s = 0.995$. In line with the literature, the impatient household's and the entrepreneur's discount factors are set at $\beta_b = 0.97$ and $\beta_e = 0.96$, respectively. See for example Iacoviello (2005), Gerali et al. (2010), Angelini et al. (2014) and Gupta and Sun (2018). The choice of these values ensures that both the impatient household's and the entrepreneur's borrowing constraints are binding in the neighbourhood of steady state. The steady-state value of gross inflation rate is set at $\pi = 1.016$, which implies the annual inflation rate of 6.4 percent in steady state fairly in line with the South African inflation data over the sample period. Together with the patient household's discount factor, this value implies a steady-state nominal interest rate of 8.5 percent per year, which is slightly higher than the sample average observed in the data over the period 2000Q1 to 2016Q4.

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	0.90
Housing preference	j	0.10	Steady-state LTV ratio (Entrep.)	m_e	0.70
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 NPLs stand for household, entrepreneur and non-performing loans, respectively.

The weight on leisure in the households' utility function is set at $\tau = 2$ in line with the literature. This value implies that households devote approximately one third of their time to working. 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). Housing weight in the utility functions is calibrated at $j = 0.12$. The choice of these values implies that the steady-state 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.[16]

Leverage ratios for the impatient household and the entrepreneur are set based on the South African credit market data over the sample period. The steady-state LTV ratio for the impatient household 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. In the case of the entrepreneur, this value is set at $m_e = 0.6$. These values are well within the observed maximum LTV ratios for a first-time mortgage buyer typically found in emerging and developing economies, including South Africa. See for example IMF (2011). These values pin down the steady-state ratio of household loans to output at approximately 0.35 while the ratio of entrepreneur loans (corporate loans) to output is 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 on household and entrepreneur loans are both set at $w_b = w_e = 1$. The discount factor for the bank is set at $\beta_f = 0.95$. This value is lower than the patient household's discount factor (β_s) and guarantees that the bank's borrowing constraint (35) is binding in the neighbourhood of the steady state. The steady-state ratios of household and entrepreneur

[16]The 2016 Property Sector Charter Council's (PSCC) report suggests that residential housing wealth constitutes approximately 80 percent of the total South Africa housing wealth while the remaining is commercial housing wealth. Source: http://www.sacommercialpropnews.co.za/property-investment/8211-sa-property-sector-volumes-to-r5-8-trillion.html.

NPLs are set at $\zeta_b = 0.04$ and $\zeta_e = 0.034$, respectively, to match their historical averages. Together with the impatient household's and the entrepreneur's 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.[17]

We set the steady-state gross markup at $X = 1.10$ in the ballpark of values widely used in the literature. See for example Liu and Seeiso (2012), du Plessis et al. (2014) and Gupta and Sun (2018) in the case of South Africa. This implies a steady-state markup of 10 percent in the retail sector. The parameter measuring the persistence of household and entrepreneur NPLs is set at $\rho_{\varepsilon b} = \rho_{\varepsilon e} = 0.7$ in line with Steinbach et al. (2014).

3.3 Prior distributions

The remaining set of parameters are estimated using Bayesian techniques. Tables 2 and 3 show prior distributions, means and standard deviations of the estimated parameters. 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 governing 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 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 the 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).

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 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 are 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.

[17] Risk-adjusted lending rate or effective lending rate is approximated by a sum of household (or corporate) lending rate as reported by South Africa Reserve Bank plus the ratio of non-performing loans.

Table 2: Prior and posterior distribution 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 Enrep. 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
Enrep. default cost parameter	ϑ_e	beta	0.50	0.10	0.0640	0.1287	0.2024
Banker loan to impatient HH adj. cost	ϕ_{bf}	gamma	0.25	0.125	0.9309	1.0396	1.1500
Banker loan to Entrep. 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) as described in An and Schorfheide (2007). HH, Entrep and NPLs stand for household, entrepreneur and non-performing loans, respectively.

3.4 Posterior estimates

The last three columns of Table 2 shows the posterior mean and the 5 and 95 percentiles of the posterior distributions of the estimated parameters.[18] The estimation procedure use the Metropolis-Hastings (MH) Markov-Chain Monte Carlo (MCMC) algorithm to obtain the posterior distribution of the parameters. We simulate two Markov-Chains each consisting of 250, 000 draws and the first 50 percent of the draws are neglected (burn-in period). We parameterise the MH with a step size (scale factor) of 0.45, which ensures an acceptance rate of approximately 26 percent.

The parameters governing habit persistence and the impatient household's labour income share are estimated to be 0.56 and 0.24, respectively. These values are fairly in line with the estimated values in Iacoviello (2015) and Gupta and Sun (2018). Calvo parameter, which measures the degree of price stickiness, is estimated at 0.51. This implies that entrepreneurs (firms) adjust prices approximately every 2 quarters. That is, $1/(1-0.51) \approx 2$. The results also imply a moderate degree of price indexation to the past inflation, at the estimated value of 0.39, for entrepreneurs (firms) who do not adjust prices every quarter.

[18] We present the prior and posterior marginal densities of the structural parameters in technical appendix A. We also performed an identification test and find that all parameters are identified. The plots of the log-posterior likelihood functions and log-likelihood kernels of the estimated parameters provide a visual confirmation that the mode-computation found the local mode and the functions of interest are indeed optimised. The Monte Carlo Markov Chain (MCMC) univariate and multivariate convergence diagnostics proposed by Brooks and Gelman (1998) also provide evidence of convergence. For brevity, we only present the multivariate convergence diagnostics plots in technical appendix B.

Table 3: Prior and posterior distribution of the shock processes.

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) as described in An and Schorfheide (2007). HH, Entrep and NPLs stand for household, entrepreneur and non-performing loans, respectively.

Turning to the parameters governing monetary policy rule, we find that the policy parameters which measure the response of the policy rate to inflation and output growth are estimated at $\phi_\pi = 1.70$ and $\phi_y = 0.56$, respectively. The results also suggest that there is a modest degree of interest rate smoothing, estimated at 0.47. These values compare favourably with Steinbach et al. (2009), Liu (2013), du Plessis et al. (2014) and Gupta and Sun (2018) in the context of South Africa and suggest that the South African Reserve Bank reacts more actively to inflation than to output. The elasticities of household and entrepreneur NPLs with respect to output growth are estimated at 0.49 and 0.45, respectively. These values are fairly in line with the estimated value in Steinbach et al. (2014) and Glen and Mondragón-Vélez (2011). The default cost parameters for the impatient household and the entrepreneur are estimated at 0.70 and 0.13, respectively. This implies that the impatient household uses approximately 70% of transfers of wealth from the bank, in the event of loan default, to pay for the costs associated with the default. On the other hand, the entrepreneur uses 13% of transfers of wealth to pay for the default costs. The default cost parameter value of 0.70 for the impatient household is lower than the estimated value of 0.99 in Zhang (2019) for the United State economy.

The results for the parameters governing the shock processes are presented in Table 3. All the shocks are highly persistent. The shock to impatient household and entrepreneur NPLs (credit supply shocks) exhibit the highest volatility in the range of 12% to 14%. This is followed by housing demand shock, which exhibits volatility of approximately 4%. The shock to the borrowing capacity of the impatient household and the entrepreneur (LTV or credit demand shocks) exhibits moderate volatility of approximately 2%. The volatility of the remaining shocks are estimated around 1%, with the monetary policy shock exhibiting the least volatility. In general, the results show that the posterior parameter estimates fall within the plausible ranges found in the literature.

4 Business cycle properties

In the following we assess the performance of the estimated model. Specifically, we evaluate how well the estimated model conforms to the actual data by comparing volatilities and correlation of output with other variables as predicted by the estimated model and those observed in the actual data.[19]

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
Nominal interest rate	0.51	0.63	0.10	-0.70
Household loans	2.28	3.12	0.46	0.55
Corporate loans	3.60	6.41	0.09	0.54

Note: To generate data moments, we use the same data that is used for estimating the model.

Table 4 shows the standard deviations of output, house prices, inflation, nominal interest rate, household loans and corporate loans and the correlations of these variables with output as calculated from the actual data and those predicted by the model.[20] The results show that the estimated model does a fairly good job of matching the data moments. The model reproduces volatilities of house prices, inflation and nominal interest rate fairly in line with the data. It also does a reasonably good job of reproducing volatilities of output, household loans and corporate loans, but somewhat overstates these volatilities. Importantly, the model does a good job in reproducing the fact that corporate loans are more volatile than household loans. Furthermore, the model reproduces the fact that corporate loans, household loans, house prices and inflation are more volatile than output whilst nominal interest rate is less volatile than output. Turning to the correlation of output with other variables, 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 overstates the correlation of output with corporate loans and inflation, it does a decent job of predicting a countercyclical (negative correlation with) inflation and a procyclical (positive correlation with) corporate loans. However, the model falls short of reproducing a positive correlation of output with nominal interest. The model predicts a negative correlation between these variables while it is positive in the data. In general, the estimated model does a reasonably good job of matching the

[19] In technical appendices C and D, we present impulse response functions (IRFs) and historical shock decompositions of selected variables to demonstrate the dynamic properties of the estimated model and to illustrate the relative importance of the structural shocks in explaining fluctuations in the real sector, the housing market and the credit market.

[20] We do not report the business cycle properties for household and entrepreneur NPLs because we have used proxies for these variables.

stylised facts observed in the South African data over the period 200Q1–2016Q4.

5 Optimal monetary and macroprudential policy analysis

In this section, we study the optimal design and the effectiveness of a simultaneous deployment of monetary and macroprudential policies in promoting financial and macroeconomic stability. As earlier mentioned, we measure macroeconomic stability in terms of volatility of inflation and output, and financial stability in terms of 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 introduce a macroprudential policy rule for capital requirement ratio, which relates capital requirement ratio to credit-to-output ratio, and investigate its interaction with a monetary policy rule. To conduct this analysis, we set the model parameters to the estimated values (posterior mean) from the previous section and use optimal simple rule (OSR) optimisation routine in Dynare to derive the optimal monetary and macroprudential policy parameters.

5.1 Policy loss function

To find the optimal policy parameters and evaluate the effectiveness of the optimal combination of macroprudential and monetary policies, we use quadratic policy loss function (welfare loss function) as an assessment criterion. Following Angelini et al. (2014) and Agénor et al. (2018), we define the 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. The 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.[21] Concerning our measures of macroeconomic stability, we assign a lower weight on output than on inflation to reflect the fact that the main objective of the monetary policy is to stabilise fluctuations in inflation. This is consistent with the inflation targeting regime that characterises South African monetary policy. Concerning our measures of financial stability, we assign a lower weight on volatility of house prices than on 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 a case where there is a single policymaker (a central bank) that pursues both financial stability and macroeconomic stability objectives using the two policy instruments; nominal interest rate and capital requirement ratio. That is, we assume that monetary and macroeconomic policies are conducted under full coordination.[22]

[21] Additional experiments were performed with different weights on volatility of output and credit-to-output ratio in the ranges $\lambda_y = [0.5,\ 1]$ and $\lambda_l = [0.1,\ 1]$. These did not change the qualitative results reported here.

[22] We leave aside a case where there are two policymakers each assigned a separate mandate; a central bank assigned macroeconomic stability mandate and a macroprudential authority assigned financial stability mandate. We do not attempt

5.2 Policy regimes

We consider two alternative policy regimes in which monetary and macroprudential policies are jointly implemented and compare their effectiveness in promoting financial and macroeconomic stability against a benchmark regime in which there is only monetary policy. A benchmark regime (Policy I) is described by the estimated monetary policy (Taylor) rule (39), as described in Section 2, which is seen as a fair representation of the monetary policy rule the South African Reserve Bank have been following to date. Under this regime, capital requirement ratio is constant. The first alternative policy regime (Policy II) is a combination of a standard Taylor rule (39) and a macroprudential policy rule for capital requirement ratio. In line with Angelini et al. (2014), a macroprudential policy rule (counter-cyclical capital requirement rule) relates capital requirement ratio to 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 credit, respectively. $\chi_l \geq 0$ measures the extent to which capital requirement ratio reacts to credit-to-output gap. The counter-cyclical capital requirement (CcCR) rule is consistent with the main objective of macroprudential policy; to protect the banking sector from excessive fluctuations in credit-to-output ratio which could have dire consequences for financial stability and negative spill-over effects on the real economy.

The second alternative policy regime (Policy III) is a combination of an augmented monetary policy (augmented Taylor) rule and a CcCR rule (45). In particular, the standard Taylor rule (39) is modified so that the policy rate also reacts to credit growth. That is:

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

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 build-up 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 to 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) which minimises Eq. (44) subject to the constraints given by the model.[23] 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

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 out for future research.

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

policy is price stability. We assume that monetary policy only provides a supporting role to financial stability objective. At the same time, 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 and standard deviations of the variables comprising of 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 (Policy II) while the bottom panel shows those of the optimal combination of an augmented monetary policy rule and the macroprudential policy rule (Policy III). To provide a detailed analysis, we conduct the optimal policy analysis conditional on a specific shock hitting the economy, with specific attention to 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 ineffective in mitigating the impact of non-financial shocks (Kannan et al.; 2012, Angelini et al.; 2014, Benes and Kumhof; 2015). Because the interest in this paper is on the role of macroprudential policy and its interaction with monetary policy, we therefore focus our analysis on housing demand shock, LTV shocks and NPL shocks. However, for robustness purposes we also conduct the analysis for technology shock and for all the shocks considered in the paper in columns 5 and 6, respectively. To conduct this analysis, we set all the model parameters at the estimated values (posterior mean) from the previous section.

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 authority 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 Policy II. The results further show that it is optimal for monetary policy to lean against credit cycles (an interest-rate response to credit growth) irrespective of the shock hitting the economy. Across all the shock scenarios, the optimal coefficient on credit growth hits the upper bound of 0.2. As highlighted in the previous section, we restrict the value of this coefficient within the range $\phi_l = [0,\ 0.2]$ for illustration purposes only. In separate experiments, we set the upper bound for ϕ_l to be greater than 0.2. The results of these experiments are qualitatively similar to those reported here. The only difference is that, financial stability benefits increase further at a much larger cost of increasing inflation volatility than those 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] Regarding the optimal design of macroprudential policy, the results suggest that the authority should adjust capital requirement ratio proportionately to credit-to-output gap (i.e., $\chi_l \approx 1$). These results hold regardless of the source of shock and whether the authority combines the macroprudential policy rule with a standard monetary policy rule (Policy II) or with an augmented monetary policy rule (Policy III).

Table 5: Optimal monetary and macroprudential policy rules and standard deviations.

Parameter	Housing demand shock	LTV shocks (credit demand)	NPL shocks (credit supply)	Technology shock	All shocks
Optimal standard Taylor rule and CcCR rule ($\phi_r = 0.47$): Policy II					
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
Optimal augmented Taylor rule and CcCR rule ($\phi_r = 0.47$): Policy III					
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 percentage difference between welfare loss under a benchmark policy regime (estimated Taylor rule) and an alternative policy regime (Policy 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. Standard deviation relative to benchmark is calculated as the standard deviation of a variable i, $i = \{\pi, y, l/y, q\}$, under the alternative regime divided by that under the benchmark regime. That is, $\sigma^2_{i,alternative}/\sigma^2_{i,benchmark}$. A value less than 1 means that the alternative regime reduces the volatility of variable i relative to the benchmark regime.

Turning to the welfare effect, the results suggest that the optimal combination of monetary policy (standard or augmented) rule and macroprudential policy rule enhances the ability of the authority to minimise the welfare loss. In comparison to Policy I (benchmark regime), both Policy II (optimal

[24] Agénor et al. (2013) also document that allowing the policy rate to react aggressive to financial variables (credit growth or credit-to-output ratio) increases volatility of the policy rate which could be a concern for the central bank as this may generates instability within the economy.

standard monetary policy rule and macroprudential policy rule) and Policy III (optimal augmented monetary policy rule and macroprudential policy rule) yield welfare gains regardless of the source of shock. Such welfare gains are far larger under Policy III than under Policy II, implying that Policy III outperforms Policy II in terms of minimising the welfare loss.

When we consider the volatilities of the variables comprising of the loss function it is evident that the welfare gains are mainly due to the reduced volatilities of output, credit-to-output ratio and house prices. Compared to Policy I, Policy II reduces volatilities of credit-to-output ratio, house prices and output but increases that of inflation. This trade-off between financial stability and price stability worsens under Policy III where the authority adjusts the policy rate to credit growth in addition to inflation and output growth. In this case, the increase in financial stability comes at a cost of a much larger increase in volatility of inflation than that under Policy II. Compared to Policy II, Policy III performs better in stabilising output, especially when the economy faces housing demand shock and LTV shocks, but performs poorly in stabilising house prices in the case of LTV and NPL shocks. These results compares favourably with Gelain et al. (2013) and Tayler and Zilberman (2016), in which the authors document that a policy regime that combines an augmented monetary policy and macroprudential policy generates a trade-off between price and financial stability.

5.4 Impulse response analysis

To gain more insights on how monetary policy interacts with macroprudential policy, in this section, we present the impulse responses of the selected variables following housing demand, LTV and NPL shocks. We contrast the benchmark regime (Policy I) with the two alternative policy regimes in which monetary and macroprudential policies co-exist: a standard monetary policy rule and macroprudential policy rule (Policy II) and an augmented monetary policy rule and macroprudential policy rule (Policy III). To conduct this analysis, we set the values of the model parameters under the benchmark regime at the estimated values (posterior mean) from the previous section. Under the two alternative policy regimes, we use the optimal values reported in Table 5 for monetary policy rules and macroprudential policy rule.

Fig. 2 shows the impulse responses of the selected variables following a positive housing demand shock. Under the benchmark regime (Policy I), the shock generates expansionary effects in the economy. It drives up house prices and, through collateral constraints, leads to an increase in both impatient household loans and entrepreneur loans. This in turn stimulates consumption and output growth. Meanwhile, inflation declines and this prompts the central bank to reduce the policy rate (nominal interest rate). Lending rates increase following the increase in demand for loans. When the authority adopts a policy regime that combines a standard monetary policy rule and macroprudential policy rule (Policy II), we see that the effects of expansionary housing demand shock are dampened. In this case, the authority increases capital requirement ratio when credit-to-output ratio increases. This prompts the bank to adjust its balance sheet by reducing the supply of credit (loans) relative to that under Policy I. The reduction in credit supply induces the impatient household and the entrepreneur to reduce demand for housing. This dampens the increase in house prices and, thus, mitigates the amplification effects of the borrowing constraints on the economy. Consequently, consumption and output do not increase as much as under Policy I and inflation declines only slightly. The adjustment in the policy rate then becomes smaller in comparison with that under Policy I.

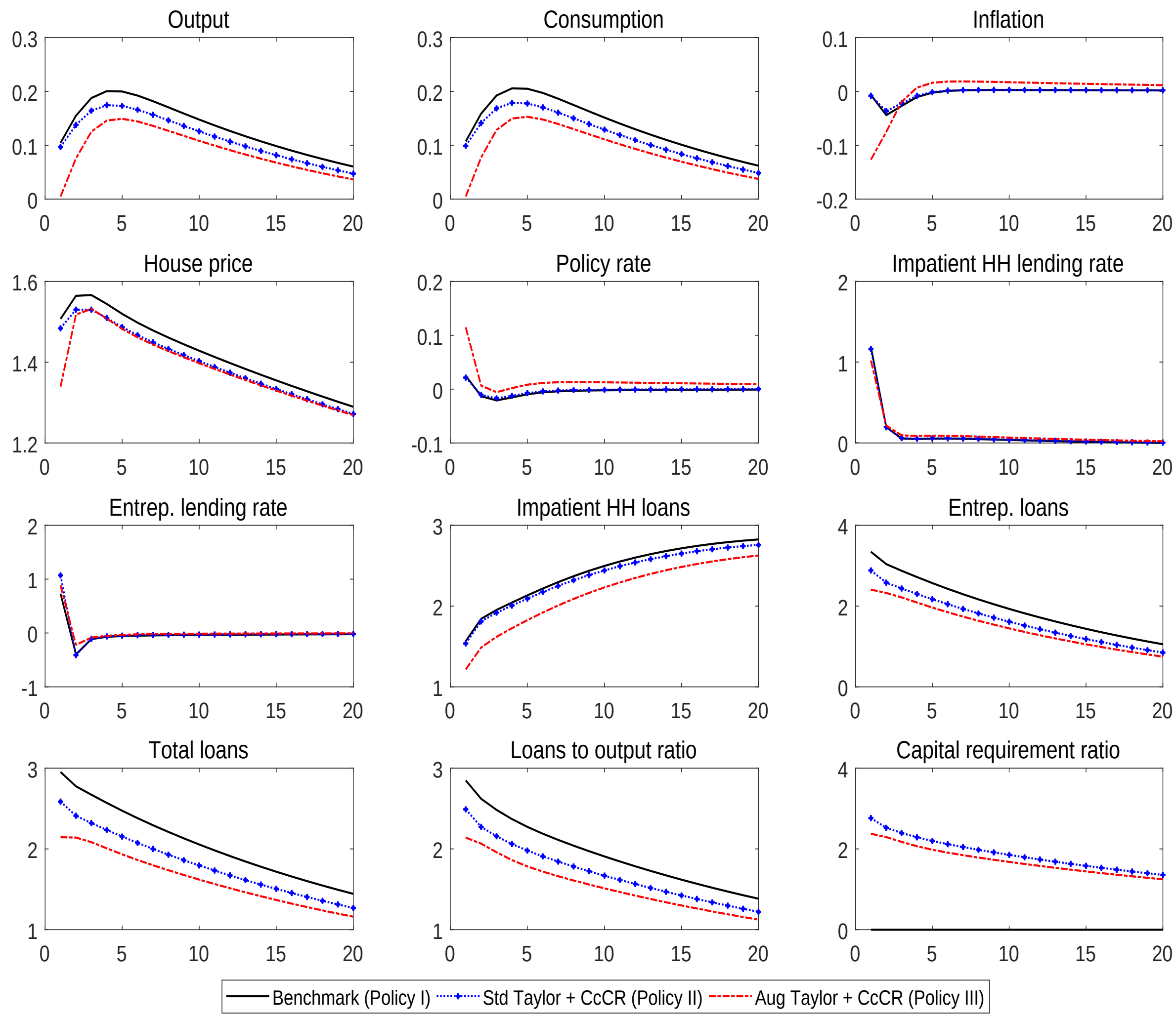


Figure 2: Impulse responses to a positive housing demand shock under the three policy regimes: Policy I, Policy II and Policy III. Variables are expressed in % deviations from the steady state, and interest rates and inflation are in percentage points. HH and Entrep stand for household and entrepreneur, respectively. *Ordinate*: time horizon in quarters.

The expansionary effects of the shock are dampened further when the authority adopts a policy regime that combines an augmented monetary policy rule and macroprudential policy rule (Policy III). In this case, the increase in credit growth prompts the authority to increase the policy rate. As a result, inflation declines by a larger margin under Policy III than under Policy II. Since the patient household consumes according to the Euler equation (4), the increase in real interest rate (combined effect of the increase in the policy rate and the fall in inflation) prompts the patient household to reduce consumption. This exerts downward pressure on aggregate demand and leads to a slight increase in consumption and output. The mechanism through which Policy III dampens the expansionary effects of the shock also operates through the expectation channel of monetary policy. Intuitively, in a policy regime where monetary policy also responds to financial conditions (credit growth), private agents would expect the policy rate to react more aggressive in order to mitigate the impact of expansionary financial shock (or shocks mainly transmitted through the credit market) than in a policy regime where monetary policy does not respond to financial conditions. In this case, forward-looking borrowers (the impatient household and the entrepreneur) take into account the potential increase in the policy rate when making economic decisions and react by reducing borrowing following the expansionary housing demand shock. Hence, impatient household loans and entrepreneur loans increase marginally under Policy III. The results further show that, under Policy III, the authority does not need to tighten capital requirement regulation as much as under Policy II. This is because monetary policy also provides a helping hand to macroprudential policy in order to foster financial stability.

Consistent with the findings in the previous sub-section, it is evident that the authority faces a trade-off between price and financial stability objectives under Policy III. Under Policy III, a sharp increase in the policy rate stabilises credit-to-output ratio, house prices as well as output, but destabilises inflation. Policy III yields a more volatile response of inflation than Policy II. Fig. 2 also highlights that an interest-rate response to financial variables (Policy III) may give rise to the conflict between price and financial stability objectives. On the one hand, the fall in inflation requires the authority to reduce the policy rate while the credit market boom requires an increase in the policy rate. Nevertheless, this policy conflict is absent under Policy II because monetary policy focuses mainly on its primary objective of price stability.

We turn next to the impact of the credit market shocks (household LTV and NPL shocks). Fig. 3 shows the impulse response functions of the selected variables following a positive household LTV shock.[25] Under the benchmark regime (black solid lines), the shock increases the borrowing capacity of the impatient household and leads to an increase in the impatient household's demand for housing. This drives up house prices and through borrowing constraint channel (housing wealth channel) generates expansionary effects in the economy. Both the impatient household and the entrepreneur increase demand for loans and, thus, stimulate aggregate spending and production. The increase in demand for loans prompts the bank to increase lending rates, especially on impact. Inflation initially increases and subsequently declines. The policy rate increases initially to counteract the increase in inflation and subsequently declines as inflation declines. Overall, consumption and output increase. As in the case of the housing demand shock, a simultaneous deployment of monetary and macroprudential policies dampens the expansionary effects of the shock. Under Policy II (blue asterisk line), the authority tightens capital requirement regulation when credit-to-output ratio increases. This induces the bank to adjust its balance sheet by reducing supply of loans to the two credit-dependent agents (the impatient household and the entrepreneur). As a result, both the impatient household and the entrepreneur reduce spending in the economy including investment in housing. This in turn dampens the increase in house prices and, thus, mitigates the amplification effect of the borrowing constraints on the real sector. As a consequence, consumption and output increase by less under Policy II than under Policy I.

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

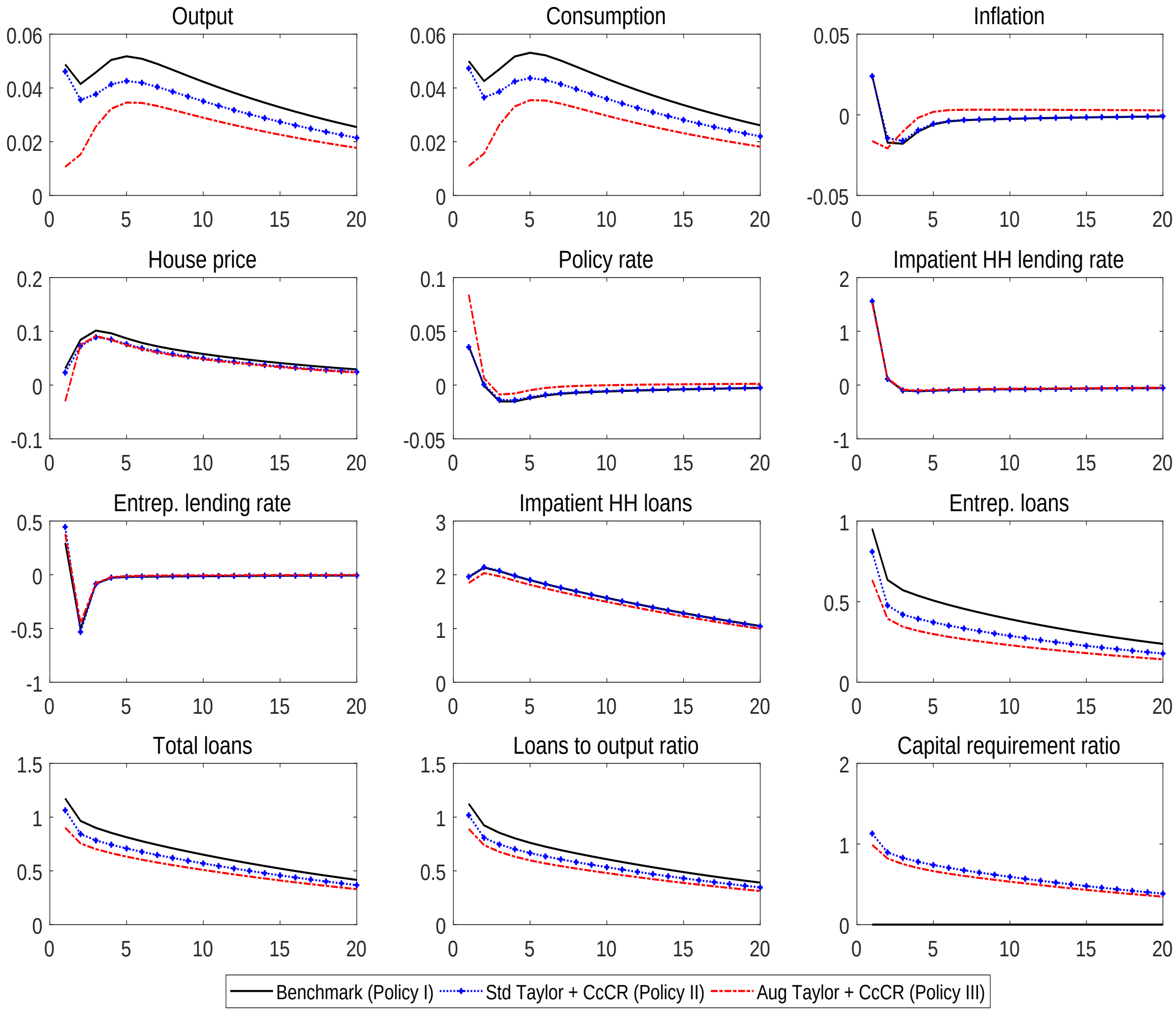


Figure 3: Impulse responses to a positive household LTV shock under the three policy regimes: Policy I, Policy II and Policy III. Variables are expressed in % deviations from the steady state, and interest rates and inflation are in percentage point deviations from steady state. HH and Entrep stand for household and entrepreneur, respectively. *Ordinate*: time horizon in quarters.

The results further show that allowing the monetary policy to react to emerging financial imbalances (Policy III) generates substantial gains in terms of dampening the impact of the shock in comparison with Policy II. The stabilisation effects of Policy III stem mainly from the expectation channel of monetary policy and intertemporal substitution effect. Through the expectation channel of monetary policy, the impatient household and the entrepreneur reduce demand for loans in anticipation of an increase in interest rates consequent upon the monetary policy reaction to credit growth.[26] The slow down in borrowing induces the impatient household and the entrepreneur to reduce spending and investment in housing which in turn dampens the increase in house prices. At the same time, a sharp increase in the policy rate and hence real interest rate under Policy III prompts the patient household to reduce

[26] In an economy where the authority adjusts the policy rate to credit growth, forward-looking agents anticipate potential increase in the policy rate following the shock that increases credit and therefore take this into account when making economic decisions.

consumption through an intertemporal substitution effect.[27] Specifically, the patient household reduces consumption and increases investment in housing to take advantage of a lower house prices under Policy III than that under Policy II. Because the policy rate increases by a larger margin under Policy III than under Policy II, the reduction in the patient household's consumption is larger under Policy III than under Policy II.

In a nutshell, the results suggest that Policy III is more successful than Policy II in dampening fluctuations in total loans, house prices, consumption and output following household LTV shock. As in the case of the housing demand shock, we find that Policy III generates a trade-off between price and financial stability. Specifically, Policy III enhances financial and output stability at the cost of destabilising inflation. Fig. 3 also shows that an interest-rate response to credit growth (Policy III) can generate excessive stabilisation effects in the real sector by overly reducing consumption and output. On the contrary, the policy regime that combines a standard monetary policy rule and macroprudential policy rule (Policy II) mitigates these costs. In particular, Policy II enhances the overall economic stability.

In Fig. 4, we compare the responses of the selected variables to a negative household NPL shock under the three policy regimes.[28] Under the benchmark regime (Policy I), the shock increases the ratio of impatient household NPLs and leads to an increase in the bank's loan losses. This in turn reduces the bank's net worth (bank capital) and forces the bank to adjust its balance sheet by reducing the total supply of loans in order to continue meeting the regulatory requirement ratio. The bank reduces supply of loans by a larger margin to the impatient household (a more risky borrower) than to the entrepreneur (a less risky borrower). In addition to this indirect effect stemming from the balance sheet adjustment, the shock prompts the bank to increase lending rates due to an increase in the perceived credit risk and in an attempt to rebuild its net worth by increasing interest rate earnings. Again, the increase in lending rate is larger for the household than for the entrepreneur. This weakens loan demand (borrowing) further and prompts credit-dependent agents (the impatient household and the entrepreneur) to reduce spending including investment in housing. The fall in demand for housing causes a decline in house prices which in turn generates a negative housing wealth effects, leading to a fall in consumption and output. Inflation, on the contrary, increases as the entrepreneur preserves internal financing (profits) by raising prices. The central bank increases the policy rate to counteract the increase in inflation.

When the authority complements a standard monetary policy rule with a macroprudential policy rule (Policy II), the negative impact of the shock on the economy is dampened. In this case, the authority relaxes capital requirement regulation when credit-to-output ratio declines. This reduces pressure on the bank to adjust its balance sheet as aggressive as under Policy I, in order to continue meeting the

[27] This is because the patient household consumes according to the Euler equation, which implies that dynamics of patient household's consumption are also driven by changes in real interest rate.

[28] For brevity, we only report the impulse responses to a negative household NPL shock. The impulse responses to a negative entrepreneur NPL shock under the three policy regimes are qualitatively similar to those reported here. The only notable difference is that entrepreneur loans declines while impatient household loans increases following the entrepreneur NPL shock. Furthermore, entrepreneur lending rate increases while impatient household lending rate falls. The impulse responses to a negative entrepreneur NPL shock are reported in technical appendix E.

regulatory requirement. As a result, total loans fall by less under Policy II than under Policy I. This mitigates the spill-over effects of the shock on the housing market and the real sector. As a consequence, house prices, consumption and output decline by less under Policy II in comparison with the fall under Policy I.

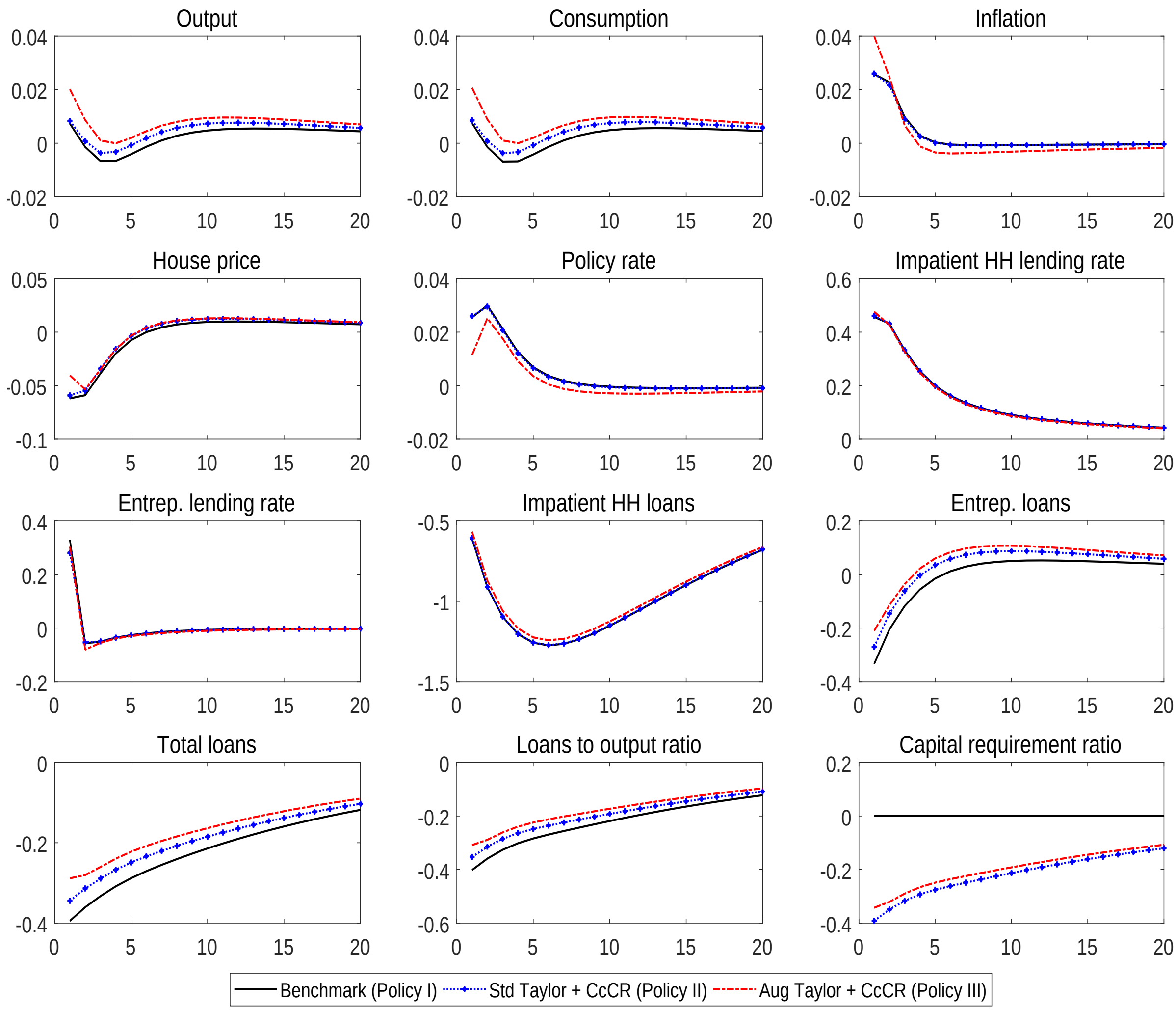


Figure 4: Impulse responses to a negative shock to impatient household non-performing loans under the three policy regimes: Policy I, Policy II and Policy III. Variables are expressed in % deviations from the steady state, and interest rates and inflation are in percentage point deviations from steady state. HH and Entrep stand for household and entrepreneur, respectively. *Ordinate*: time horizon in quarters.

Fig. 4 also show that the stabilisation effects increase further when the authority combines an augmented monetary policy rule with a macroprudential policy rule (Policy III). In this case, the policy rate increases by a lesser magnitude than the increase under Policy II. This is because the policy rate also responds to deteriorating financial conditions. Because of a lower increase in the policy rate, inflation increases by a larger magnitude under Policy III than under Policy II, particularly on impact. As a result, real interest rate declines and this in turn prompts the patient household to increase consumption and reduce investment in housing through an intertemporal substitution effects. At the same time, in anticipation of a decline in the policy rate consequent upon a monetary policy reaction to a fall in credit growth, forward-looking borrowers (the impatient household and the entrepreneur) increase demand for loans following the shock. Consequently, the impatient household's and the entrepreneur's spending including investment in housing fall by less under Policy III than that under Policy II. This mitigates the fall in house prices and, through the borrowing constraints, mitigates the negative impact of the shock on real sector by more in comparison with Policy II. The combined effect of the expectation channel of monetary policy and intertemporal substitution effect is a larger attenuation effects of the shock on total loans, house prices, consumption and output under Policy III than under Policy II. Similar to the case of housing demand shock and LTV shock, we find that Policy III outperforms Policy II in dampening fluctuations in the credit market, the housing market and the real sector. Nonetheless, this comes at the expense of increasing fluctuations in inflation.

The main conclusions drawn from this analysis are as follows. The authority faces a trade-off between price and financial stability objectives when monetary policy also responds to credit growth. While this policy option seems attractive from the financial stability point of view, it has a potential to compromise price stability and introduce uncertainty within the economy. Consistent with the findings in Tayler and Zilberman (2016), we establish that even a small reaction to credit growth (setting $\phi_l = 0.01$) increases fluctuations in inflation but dampens fluctuations in credit and output. Furthermore, an interest-rate response to credit growth gives rise to a conflict between price stability objective and financial stability objective, especially in the case of the shocks which generate a negative correlation between credit and inflation. As noted in our analysis, a shock to either housing demand, LTV or NPLs generates a negative correlation between credit and inflation. In this case, the authority is forced to choose between price stability or financial stability when deploying an augmented monetary policy rule. The interest-rate response required to achieve price stability is inconsistent with that required to achieve financial stability.[29] As we have seen in the impulse response analysis, this conflict compromises the ability to deliver on price stability mandate. Nevertheless, the trade-off between price and financial stability objectives is minimised and the policy conflict is absent under Policy II. Our analysis implies that a policy regime that combines a standard monetary policy rule and macroprudential policy rule delivers a more stable economic system than the one that combines an augmented monetary policy rule and macroprudential policy rule.

5.5 Efficient Policy Frontiers

In this section, we compare the outcomes of the three policy regimes in terms of two-dimensional efficiency policy frontiers on output versus inflation volatility and credit-to-output ratio versus inflation volatility. The efficiency policy frontier shows the locus of the volatilities of key policy variables (inflation, output and credit-to-output ratio) calculated at each set of optimal policy coefficients that are obtained for different combinations of loss function weights. As in the previous section, we compare the outcome of the benchmark regime (Policy I) with the two alternative policy regimes: a combination of a standard

[29] For example, a positive housing demand shock increases credit (loans) 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 in the policy rate. The opposite is also true in the case of a negative shock.

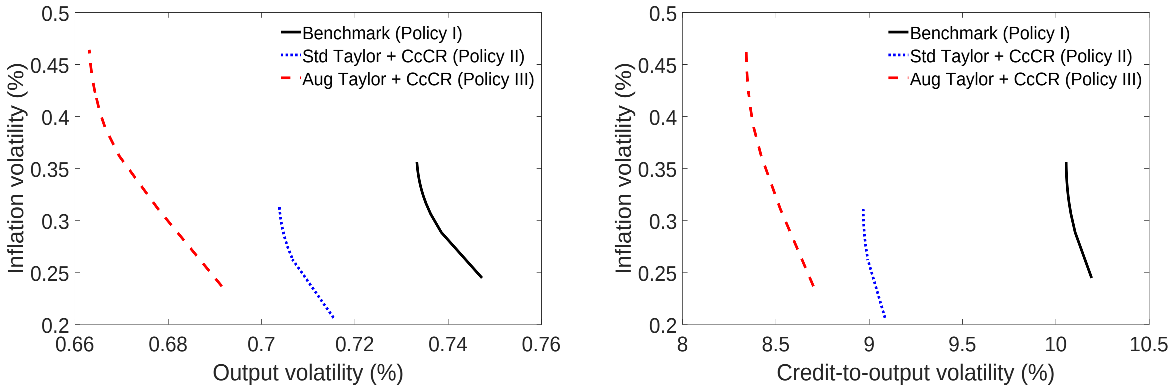
monetary policy rule and macroprudential policy rule (Policy II) and a combination of an augmented monetary policy rule and macroprudential policy rule (Policy III). To perform the exercise, we simplify the loss function (44) by setting the weights on the volatilities of output and house prices to 0.5 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. 5a shows the efficiency policy frontiers on inflation and output volatility when the economy faces housing demand shock. Moving from right to left in Fig. 5a, the weight on the volatility of credit-to-output ratio ($\lambda_{l/y}$) increases from 0 to 1. The curve that is closer to the origin represents the efficient (preferred) policy regime in terms of reducing volatilities of inflation and output. The efficiency policy frontiers under the three policy regimes present a clear trade-off between inflation and output volatility, as the authority adjusts preference for stabilising credit-to-output ratio relative to stabilising inflation and output. The maximum attainable reduction in output volatility can be achieved at the expense of increasing inflation volatility. The results show that the introduction of macroprudential policy shifts the efficiency frontier to the left, implying a more efficient policy outcome in terms of a lower volatilities of inflation and output relative to those under the benchmark regime (the monetary-policy-only regime). This means that macroprudential policy also acts as a tool to stabilise output. This is because macroprudential policy exerts a dampening effects on credit supply and, in an economy where credit finances consumption and production, a more stable supply of credit means a stable consumption and output. The results further show that Policy III outperforms Policy II in terms of stabilising output whilst Policy II outperforms Policy III in stabilising inflation. Policy III delivers the largest reduction in output volatility while Policy II delivers the largest reduction in inflation volatility.

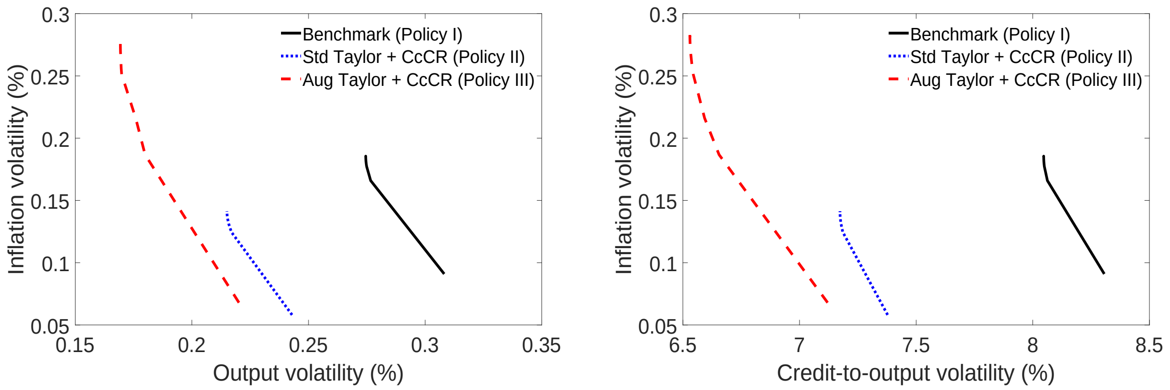
Fig. 5b shows the efficiency policy frontiers on volatilities of inflation and credit-to-output ratio. We see that the introduction of macroprudential policy enhances both financial and price stability, especially under Policy II. The efficiency frontier corresponding to Policy II is closer to the origin (inflation and credit-to-output ratio volatility axes) than the one corresponding to Policy I, implying a more efficient policy outcome. Policy II reduces volatility of credit-to-output ratio for any given level of inflation volatility and vice versa. A comparison between Policy II and Policy III suggests that Policy II is more efficient than Policy III in promoting financial and price stability. This is because Policy II not only reduces volatility of credit-to-output ratio, but also reduces that of inflation relative to Policy I. Policy III is more efficient than Policy II in promoting financial stability, but less efficient than Policy II in promoting price stability. Specifically, Fig. 5b shows that Policy III delivers the largest reduction in volatility of credit-to-output ratio, but at the expense of a higher inflation volatility than those under Policy II and under Policy I.

We also conduct similar analysis for LTV (household and entrepreneur) shocks and NPL (household and entrepreneur) shocks in Figs. 6 and 7. The same conclusions as those drawn in the case of housing demand shock also emerge. In a way, the efficient policy frontier analysis reaffirms the findings in the previous section. A policy regime that combines a standard monetary policy and macroprudential



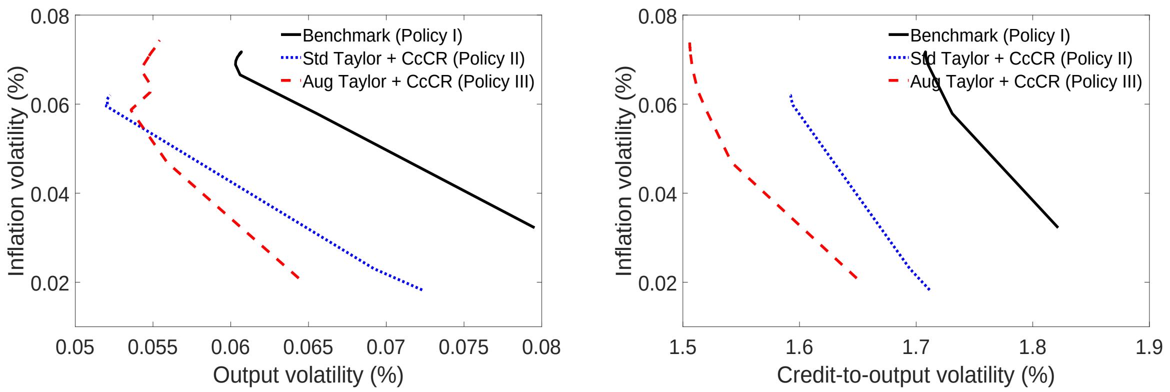
(a) Output vs inflation (b) Credit-to-output ratio vs inflation

Figure 5: The efficiency policy frontiers following housing demand shock ($\lambda_{l/y} \in [0, 1]$).



(a) Output vs inflation (b) Credit-to-output ratio vs inflation

Figure 6: The efficiency policy frontiers following LTV shocks ($\lambda_{l/y} \in [0, 1]$).



(a) Output vs inflation (b) Credit-to-output ratio vs inflation

Figure 7: The efficiency policy frontiers following NPL shocks ($\lambda_{l/y} \in [0, 1]$).

policy unambiguously enhances both macroeconomic 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 counter-cyclical LTV regulation enhances overall economic stability. On the other hand, our analysis suggests that a policy regime that combines an augmented monetary policy and macroprudential policy has a potential to compromise price stability. In line with Rubio (2016) and Gelain et al. (2013), we show that an augmented monetary policy (an interest-rate response to credit growth) enhances financial stability at the expense of price stability.

6 Optimal simple rules conditional on the estimated Taylor rule

In the previous section, we conduct the optimal policy analysis by optimising over all the policy parameters in monetary policy rules (standard or augmented rules) and macroprudential policy rule. This analysis showed that the optimal combination of monetary policy rule (either standard or augmented) and macroprudential policy rule enhances financial stability but at the cost of increasing inflation volatility. This is because the optimal (standard or augmented) monetary policy rule features a lower response to inflation and a higher response to output than the estimated responses under the benchmark regime. This compromises the effectiveness of monetary policy to counteract fluctuations in inflation but enhances its effectiveness in promoting output and financial stability. In this section, we establish whether the trade-off between price and financial stability can be reduced or eliminated when the authority follows the estimated monetary policy rule and only optimise over the policy parameters on credit growth in the augmented monetary policy rule and credit-to-output ratio in the macroprudential policy rule. In this case, the monetary policy rule features a stronger response to inflation and a moderate response to output in comparison with the optimal monetary policy rules reported in Table 5.

The results of this analysis are presented in Table 6. In general, the results of the optimal policy parameters and welfare gains are qualitatively similar to those reported in Table 5 where we allow all the policy parameters in the monetary policy rules to be chosen optimally. In particular, the optimal values of the policy parameters on credit growth in the augmented monetary policy rule and on credit-to-output ratio in the macroprudential policy rule are remain the same as those reported in Table 5. It is also evident that a simultaneous deployment of monetary policy rule (standard or augmented) and macroprudential policy rule improves the welfare in comparison with the benchmark regime, regardless of the nature of the shock hitting the economy. The policy regime that combines an augmented monetary policy rule and macroprudential policy rule (Policy III) yields the highest welfare gains compared to the one that combines a standard monetary policy rule and macroprudential policy rule (Policy II).

Turning to the volatilities of the variables comprising of the loss function, the results show that Policy II reduces volatilities of output, credit-to-output ratio and house prices without increasing that of inflation. In the case of LTV shocks and technology shock, Policy II not only stabilises output, credit-to-output ratio and house prices, but also inflation. In the case of housing demand shock, NPL shocks and multiple shocks it enhances financial stability at no cost to price stability. Nonetheless, Policy III (irrespective of whether monetary policy rule features a strong reaction to inflation) stabilises output, credit-to-output ratio and house prices at the cost of increasing inflation volatility. Compared to the results reported in Table 5, we observe that a policy combination of a monetary policy rule, that features

Table 6: Optimal policy rules conditional on the estimated Taylor rule.

Parameter	Housing demand shock	LTV shocks (credit demand)	NPL shocks (credit supply)	Technology shock	All shocks
Estimated Taylor rule and optimal CcCR rule ($\phi_r = 0.47$; $\phi_\pi = 1.70$; $\phi_y = 0.56$)**: Policy II**					
χ_l	1.12	1.12	1.12	1.12	1.12
Welfare gain (%)	20.15	23.16	15.44	1.80	15.12
Standard deviation relative to benchmark					
π_t	1.00	0.80	1.00	0.97	1.00
Y_t	0.93	0.77	0.88	1.00	1.00
L_t/Y_t	0.88	0.88	0.92	0.90	0.88
q_t	0.99	0.78	0.83	1.00	0.99
Optimal augmented Taylor rule and CcCR rule ($\phi_r = 0.47$; $\phi_\pi = 1.70$; $\phi_y = 0.56$)**: Policy III**					
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 (%)	30.68	38.49	29.73	5.17	24.71
Standard deviation relative to benchmark					
π_t	3.40	2.80	1.67	1.25	1.11
Y_t	0.86	0.57	0.75	0.99	0.99
L_t/Y_t	0.81	0.78	0.84	0.70	0.80
q_t	0.99	0.78	0.92	0.99	0.99

Notes: Welfare gain is calculated as percentage difference between welfare loss under a benchmark policy regime (estimated Taylor rule) and an alternative policy regime (Policy 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. Standard deviation relative to benchmark is calculated as the standard deviation of a variable i, $i = \{\pi, y, l/y, q\}$, under the alternative regime divided by that under the benchmark regime. That is, $\sigma^2_{i,alternative}/\sigma^2_{i,benchmark}$. A value less than 1 means that the alternative regime reduces the volatility of variable i relative to the benchmark regime.

a strong reaction to inflation, and macroprudential policy rule delivers a better stabilisation outcome, which do not only include output, credit-to-output ratio and house prices stability, but also inflation stability. In a nutshell, this analysis suggests that the trade-off between price and financial stability can be reduced when the authority combines a monetary policy, that gives prominence to price stability, with a macroprudential policy. In particular, the analysis suggests that a policy combination of a standard monetary policy rule, that features a strong reaction to inflation, and a macroprudential policy rule delivers both financial and macroeconomic stability.

7 Conclusion

In this paper, we study the optimal design and the interaction between monetary and macroprudential policies in a context of an estimated DSGE model, for South African economy, that features financial frictions, a housing market and a stylized banking sector. We consider two alternative policy regimes in which monetary and macroprudential policies are jointly implemented and compare their effectiveness in promoting financial and macroeconomic stability against a benchmark policy regime in which there is only monetary policy. We find that a simultaneous deployment of monetary and macroprudential policies enhances financial and macroeconomic stability, especially when monetary policy does not react to financial conditions. The policy regime that combines credit-augmented monetary policy with macroprudential policy delivers the highest welfare gains, but at a much larger cost of price instability than the one that combines a standard monetary policy with macroprudential policy. The efficient policy frontier analysis shows that a policy combination of a standard monetary policy and macroprudential policy is the most efficient policy regime in terms of enhancing both financial stability and macroeconomic stability. This policy regime unambiguously enhances both financial stability and macroeconomic stability. Although the policy combination of an augmented monetary policy and macroprudential policy is the most efficient policy regime in enhancing output and financial stability, it is the least efficient regime to deliver price stability.

The policy implication of our findings is that the authority should be cautious when allowing monetary policy to react to emerging financial imbalances. In particular, our analysis suggests that the authority should not use monetary policy to lean against the wind of credit cycles in an attempt to promote financial stability, at least from a positive perspective. Rather the authority should introduce macroprudential policy instrument (like countercyclical capital requirement studied here) with a primary objective of financial stability and let monetary policy to focus exclusively on its primary objective of macroeconomic (price) stability. Such a policy coordination facilitates a simultaneous pursuit of both macroeconomic (price) and financial stability objectives as documented in Badarau and Popescu (2014) and Cesa-Bianchi and Rebucci (2017). In a way, our findings are in line with the so-called the 'Tinbergen principle' that having as many policy instruments as policy objectives improves the policy outcome.

To further deepen our understanding of macroprudential policies, the analysis in this paper could be extended in several ways. One potential avenue would be to extend this analysis to a small open economy model. Such an extension would allow for an examination of the impact of foreign financial shocks and the stabilisation role of monetary and macroprudential policies. Another possible avenue would be to introduce other macroprudential policy instruments such as loan-to-value regulations or dynamic provisioning and explore the extent to which they could complement countercyclical capital requirement regulation.

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A Complete set of equations for log-linearised model

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

Patient Households

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

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

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

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

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

Impatient Households

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\frac{c_e}{y}\hat{c}_{e,t} = \frac{l_e}{y}\Big[\hat{l}_{e,t} - \frac{r_e}{\pi}[1-\zeta_e(1-\vartheta_e)](\hat{l}_{e,t-1}+\hat{r}_{e,t}-\hat{\pi}_t) + \zeta_e(1-\vartheta_e)\frac{r_e}{\pi}\hat{\zeta}_{e,t}\Big] - \frac{qh_e}{y}(\hat{h}_{e,t}-\hat{h}_{e,t-1}) + \frac{1}{x}(\hat{y}_t - \hat{x}_t) - \frac{wn_s}{y}(\hat{w}_{s,t}+\hat{n}_{s,t}) - \frac{wn_b}{y}(\hat{w}_{b,t}+\hat{n}_{b,t}) \tag{A.21}$$

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

The bank

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

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

$$\Gamma_{fb2}(\hat{r}_{b,t} - \hat{\pi}_{t+1}) = \Big(\beta_f\frac{r_b}{\pi} - \Gamma_{fb2}\Big)\hat{\zeta}_{b,t+1} - (1-w_b\kappa)\lambda_{fss}\Gamma_{fb3}(\hat{\lambda}_{f,t} - \hat{u}_{cf,t}) + w_b\kappa\lambda_{fss}\Gamma_{fb3}\hat{\kappa}_t - \Gamma_{fb1}(\hat{u}_{cf,t+1} - \hat{u}_{cf,t}) + \phi_{bf}(\hat{l}_{b,t} - \hat{l}_{b,t-1}), \tag{A.24}$$

$$\Gamma_{fe2}(\hat{r}_{e,t+1} - \hat{\pi}_{t+1}) = \Big(\beta_f\frac{r_e}{\pi} - \Gamma_{fe2}\Big)\hat{\zeta}_{e,t+1} - (1-w_e\kappa)\lambda_{fss}\Gamma_{fe3}(\hat{\lambda}_{f,t} - \hat{u}_{cf,t}) + w_e\kappa\lambda_{fss}\Gamma_{fe3}\hat{\kappa}_t - \Gamma_{fe1}(\hat{u}_{cf,t+1} - \hat{u}_{cf,t}) + \phi_{ef}(\hat{l}_{e,t} - \hat{l}_{e,t-1}), \tag{A.25}$$

$$\frac{d}{y}\hat{d}_t = (1-w_b\kappa)\frac{l_b}{y}\Big[\Gamma_{fb3}\hat{l}_{b,t} - \frac{r_b}{\pi}\zeta_b\Big(\hat{r}_{b,t} - \hat{\pi}_{t+1} + \hat{\zeta}_{b,t+1}\Big)\Big] - w_b\kappa\Gamma_{fb3}\frac{l_b}{y}\hat{\kappa}_t - w_e\kappa\Gamma_{fe3}\frac{l_e}{y}\hat{\kappa}_t + (1-w_e\kappa)\frac{l_e}{y}\Big[\Gamma_{fe3}\hat{l}_{e,t} - \frac{r_e}{\pi}\zeta_e\Big(\hat{r}_{e,t+1} - \hat{\pi}_{t+1} + \hat{\zeta}_{e,t+1}\Big)\Big], \tag{A.26}$$

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 is obtained from the South African Reserve Bank database. The exceptions are data on house prices, short-term nominal interest rate and population, which are obtained from ABSA bank (one of the leading banks in South Africa), the International Monetary Fund's (IMF's) International Financial Statistics (IFS) database and the World Bank database, respectively.

1. **Output** (y_t): Real gross domestic product (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. This data is deflated by the GDP deflator to get 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. This data is deflated by the GDP deflator to get real counterpart.

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

5. **Inflation** (π_t): Inflation is measured by quarterly changes in implicit 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 is provided in an annualised form, we transformed it into quarterly data by dividing the original data by 400 to match the frequency of the model. This data is obtained from the International Monetary Fund's (IMF's) International Financial Statistics (IFS) database.

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

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