Is Basel III counter-cyclical: The case of South Africa?

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Abstract

This paper develops a dynamic general equilibrium model with banking and a macro-prudential authority, and studies the extent to which the Basel III bank capital regulation promotes financial and macroeconomic stability in the context of South African economy. The decomposition analysis of the transition from Basel II to Basel III suggests that it is the counter-cyclical capital buffer that effectively mitigates the pro-cyclicality of its predecessor, while the impact of the conservative buffer is marginal. Basel III has a pronounced impact on the financial sector compared to the real sector and is more effective in mitigating fluctuations in financial and business cycles when the economy is hit by financial shocks. In contrast to the credit-to-GDP ratio, the optimal policy analysis suggests that the regulatory authority should adjust capital requirement to changes in credit and output when implementing the counter-cyclical buffer.

Keywords: Bank capital regulations, Financial stability, Counter-cyclical capital buffer, DSGE
JEL Classification: E44, E47, E58, G28

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1 Introduction

The recent financial crisis has highlighted that the Basel II regulatory framework is inadequate to safeguard the financial system as a whole. Among others, the crisis has provided evidence that the framework could not enable banks to cope with adverse effects of negative financial shocks, forcing them into rapid de-leverage and credit squeeze with dire consequences for the real economy. Even prior to the crisis, Kashyap and Stein (2004) and Gordy and Howells (2006) raise concerns on one potential shortcoming of the regulatory framework – Basel II is pro-cyclical.[1] The reasoning is that, under the internal ratings based approach, banks are required to hold less capital in the upswing of the business cycle and more in the downswing of the cycle. That is, the Basel II capital regulation promotes excessive credit growth in economic booms and discourages credit extension in recessions. This amplifies financial and business cycles and has negative implications for financial and macroeconomic stability.

Against this backdrop, the Basel III bank capital regulation was introduced in 2010 with the overall objective of achieving financial stability. Among others, Basel III increases the quality and quantity of bank capital to enhance banks' ability to absorb losses in periods of stress. In addition, the new regulatory framework provides macroprudential overlay to attenuate the build-up of systemic risk over time. To achieve this, over and above the minimum capital requirement of 8 percent of risk-weighted assets, the new framework requires banks to hold a mandatory 2.5 percent capital conservation buffer. Moreover, to overcome the pro-cyclicality of Basel II, the new framework introduces a counter-cyclical capital buffer. That is, banks will be required to increase their capital (by up to 2.5 percent) in good times to curb excessive credit growth and prevent the build-up of systemic vulnerability. In the downturn, when systemic risk has materialized, the buffer will be released to assist banks to cope with the shock and cover for losses, without jeopardizing their ability to meet the regulatory requirement (BCBS, 2009).

Although the broader objective of the counter-cyclical capital buffer is clear[2], its effectiveness, transmission mechanisms, and impact on the financial sector and the real economy remain imperfectly understood. This is especially the case in the context of emerging markets economies (EMEs), such as South Africa (SA). Most studies focus on developed countries (e.g., Angeloni and Faia; 2013, Angelini et al.; 2014, Benes and Kumhof; 2015, Karmakar; 2016, Rubio and Carrasco-Gallego; 2016) and little has been done in the context of EMEs. Furthermore, how to implement the counter-cyclical capital buffer still remains an open question. The Basel Committee on Banking Supervision (BCBS) only provides a reference guide as a starting point and encourages national authorities to use their own judgement when implementing the tool. In addition, it is still debatable whether the new bank capital regulation (in its current form) will help to mitigate the pro-cyclical effects of Basel II. In particular, Repullo and Saurina (2011) and Edge and Meisenzahl (2011) criticise the design of Basel III, especially the use of the credit-to-GDP ratio as a reference guide for taking buffer decisions. In the context of SA, the reserve bank also

[1] This is supported by Covas and Fujita (2010), Angelini et al. (2010), Liu and Seeiso (2012) and Repullo and Suarez (2013).

[2] As in BCBS (2010), "The primary aim of the counter-cyclical capital buffer regime is to use a buffer of capital to achieve the broader macroprudential goal of protecting the banking sector from periods of excess aggregate credit growth that have often been associated with the build-up of system-wide risk."

raises concerns regarding the proposed counter-cyclical capital rule (SARB, 2011). The argument is that the Basel III capital requirement, based on the credit-to-GDP ratio as a reference guide, has potential to exacerbate the pro-cyclicality of bank capital regulation, especially in countries where the credit-to-GDP ratio is negatively correlated with output (business cycle).

The paper builds on the growing literature on the implications of Basel III capital requirements. The main message from recent studies is that Basel III enhances the resilience of the banking sector for greater financial and economic stability. In particular, the literature establishes that the counter-cyclical capital buffer is effective in stabilizing financial and macroeconomic fluctuations, especially when the economy is hit by financial shocks. For instance, Clerc et al. (2015) and Karmakar (2016) show that higher capital requirements and the counter-cyclical capital buffer are effective in mitigating fluctuations in financial and business cycles and improving welfare. These findings are consistent with Repullo and Suarez (2013), Repullo (2013) and Gersbach and Rochet (2017), who provide the rationale for cyclically-adjusted capital requirements of Basel III. In particular, Repullo (2013) shows that cyclically-adjusted capital requirements mitigate credit squeeze and sharp decline in investment in the downswing of the business cycle. Gersbach and Rochet (2017) also postulate that counter-cyclical capital requirements are effective in attenuating excessive credit fluctuations and have potential to enhance social welfare.

The main contribution of this paper is to investigate the extent to which Basel III bank capital requirements mitigate the pro-cyclicality of its predecessor and, in turn, attenuate fluctuations in financial and business cycles and foster greater financial stability. To do this, we decompose the transition from Basel II to Basel III into two stages, namely the increase of the capital adequacy ratio (CAR) by 2.5 percent in line with the conservation buffer and the additional counter-cyclical capital buffer. With this decomposition analysis, we are able to investigate whether Basel III is able to, and through which channels, attenuate the pro-cyclicality of Basel II. This is in contrast to the existing literature, in which most studies focus on the interaction between Basel III capital requirements and monetary policy.[3] The second contribution of the paper is to establish the optimal policy rule for implementing the Basel III counter-cyclical buffer. By considering four different policy rules in the optimal policy analysis, we identify the most effective one in terms of financial and macroeconomic stabilization benefits. Lastly, to the best of our knowledge, this study is the first to use a general equilibrium framework to evaluate the implications of Basel III bank capital requirements for the SA economy. The only related study on the SA economy is Liu and Seeiso (2012), in which the authors develop a Dynamic Stochastic General Equilibrium (DSGE) model and study the impact of the Basel II bank capital regulation on business cycle fluctuations. Their results show strong evidence of the pro-cyclicality of Basel II.

To achieve these objectives, we develop a real business cycle DSGE model with a stylised banking sector and macroprudential authority. Specifically, the model builds on the framework of Iacoviello (2005, 2015) and incorporates an explicit role for macroprudential policy along the lines of Angelini et al. (2014) and Rubio and Carrasco-Gallego (2016). Since this paper purely focuses on bank capital requirements and financial stability, the model abstracts from nominal rigidities. The definition and measurement of

[3] See, for instance, Angeloni and Faia (2013), Cecchetti and Kohler (2014), Angelini et al. (2014, 2015), Benes and Kumhof (2015) and Rubio and Carrasco-Gallego (2016).

financial stability remain controversial in the literature (Galati and Moessner; 2013, Kahou and Lehar; 2017). In this study, following Rubio and Carrasco-Gallego (2014) and Agénor and Pereira da Silva (2017), we measure financial stability in terms of variability of credit (or credit-to-output ratio) and housing prices. It is also for this reason that we adopt the workhorse of Iacoviello (2005) as our model framework.

The results suggest that it is the introduction of the counter-cyclical capital buffer that effectively mitigates the pro-cyclical effects of Basel II and stabilises financial and business cycles. In contrast, the increase in CAR (2.5 % conservation capital buffer) has marginal effects in attenuating the pro-cyclicality of Basel II. We also establish that the implications of the new bank capital regulation for the financial sector and the real economy differ and are shock dependent. Firstly, the transition from Basel II to Basel III has pronounced effects on the financial sector, irrespective of the shock hitting the economy. Secondly, it mitigates the negative effects of financial shocks (loan repayment shocks) and fluctuations in financial and real variables. Thirdly, when the economy is hit by productivity and housing demand shocks, it has pronounced attenuation effect on the financial sector, while the impact on output, aggregate consumption and housing prices is muted.

The comparison analysis of different policy rules suggests that the most effective rule for setting the counter-cyclical buffer is the one in which the authority adjusts bank capital requirement to changes in credit and output. Its optimal implementation requires the authority to aggressively respond to changes in output. This, however, can be resolved by including housing prices in the capital requirement rule. These findings hold irrespective of whether the objective of the regulatory authority is financial stability only or both financial and macroeconomic stability. In addition, the optimized policy coefficients remain virtually unchanged, regardless of the policy objective.

The rest of the paper is organised as follows. The next section highlights some stylised facts about the relationships between bank lending, housing prices and the business cycle in SA. Section 3 introduces the model framework in detail, while section 4 presents calibration. Section 5 discusses business cycle properties of the model. In section 6, we investigate whether the new regulatory framework is indeed counter-cyclical based on the decomposition analysis of the transition from Basel II to Basel III. Section 7 studies the optimal rule for implementing counter-cyclical capital buffers. Section 8 concludes.

2 Stylized Facts: Financial variables, housing prices and the business cycle in SA

This section presents the empirical evidence regarding the relationships between South African housing prices, financial and key macroeconomic data over the period 1994Q1 - 2016Q4.[4] We first highlight the co-movement between these variables and then provide a more formal analysis by considering the vector autoregressive (VAR) evidence on the impact of a positive housing price shock and a negative bank capital shock. Both empirical exercises serve as references for the development and evaluation of the DSGE model in the paper.

[4]Data source: South African Reserve Bank (SARB).

2.1 The data

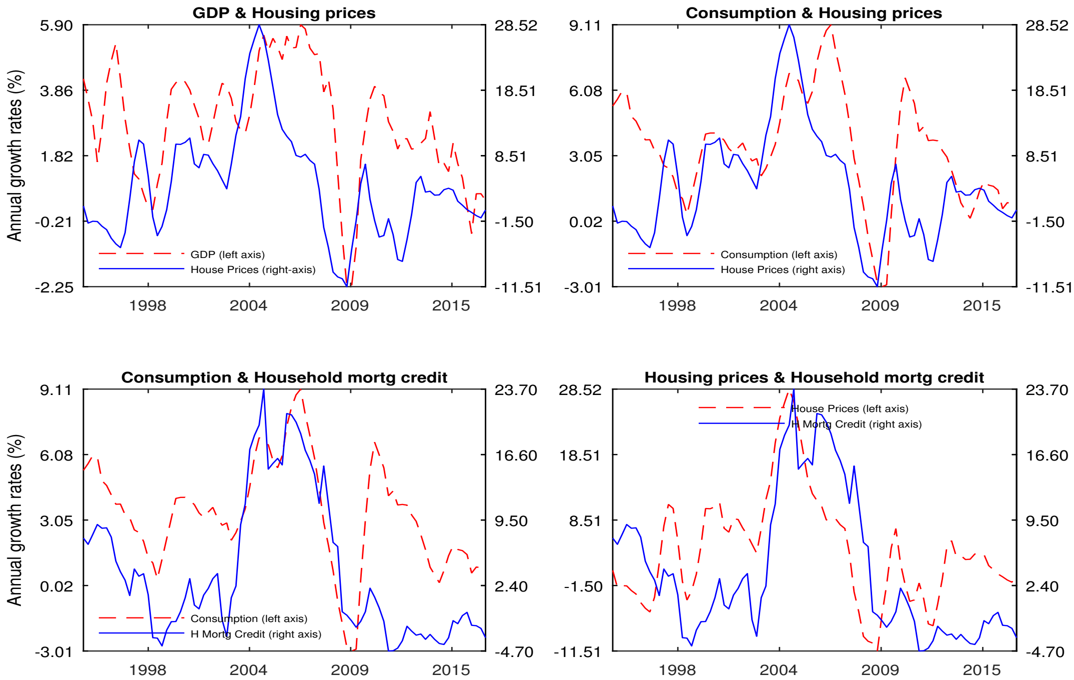

Figure 1: Relationships between housing prices, financial and key macroeconomic variables in SA.

Figure 1 plots the annual growth rates of bank credit, housing prices and the key macroeconomic aggregates, such as household consumption and output. The upper panel in figure 1 shows the relationships between housing prices, output and consumption. It is clear that housing prices co-move closely with consumption and output, with housing prices leading consumption and output growth. In particular, SA's housing boom period (2000 - 2006) is characterised by sustain increase in housing prices, consumption and output. During the 2007-08 financial crisis period, the trend is reversed with the slowdown in housing price inflation and subsequent decline in 2009, followed by the slowdown in consumption and output growth. Prior to 1998 and during the period 2010 - 2013, there is little (or no) indication of the co-movement between housing prices and the two macroeconomic aggregates.

The lower panel in figure 1 highlights the relationships between housing prices, household consumption and household mortgage credit. It is evident that housing prices and consumption move in tandem with mortgage debt over the sample period. The intuition behind the observed relationship goes as follows. An increase in housing prices generates positive wealth effects through which households (home-owners) borrow more and increase their spending on consumption. This is particularly so when housing wealth is used as collateral in the credit market to secure credit. The increase in demand for consumption goods, consequent upon housing prices increase, provides incentive for firms to increase production. Hence the positive relationship between housing prices and output observed in the upper panel in figure 1.

Figure 2 depicts the relationships between housing prices and total mortgage credit (left panel), and bank capital and total mortgage credit (right panel). It shows that housing prices and mortgage credit move together closely, with housing prices leading total mortgage debt. The only exceptional periods are prior to 1997 and the period 2012 - 2015, when the two series move in opposite directions. The right panel of figure 2 also provides evidence of the co-movement between bank credit and bank capital. Specifically, the co-movement between the two series is evident during the period 2002 - 2008. Prior to 2002 (the period associated with the 1997/98 Asian crisis) and during the post 2007/08 financial crisis period, the two series move in opposite directions. Intuitively, during the financial crisis, while being restrained from lending banks still need to engage in measures to replenish their capital positions to meet regulatory requirements.

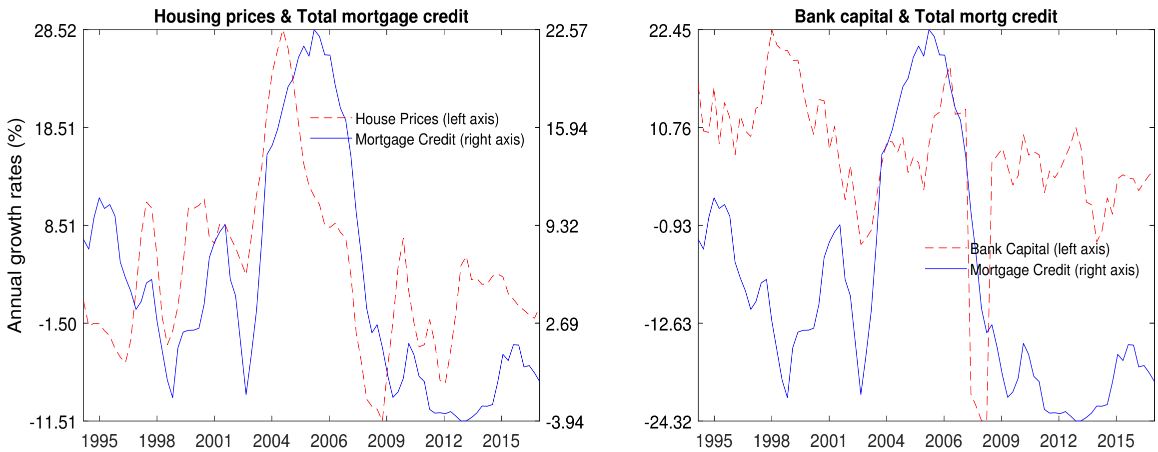

Figure 2: Relationships between housing prices, bank credit and bank capital in SA.

2.2 VAR Evidence

In this section, we establish the extent to which bank capital and housing prices shocks shape the dynamics of the financial sector and the real economy from an empirical perspective. The unrestricted VAR contains six variables, namely GDP, consumption, housing prices, bank capital, the lending rate and bank credit over the sample period 1994Q1 - 2016Q4. We use share capital and reserves as measures for bank capital, and total mortgage credit to households and corporates for bank credit. Nominal variables are deflated by GDP deflator to get their real counterparts. The real interest rate is obtained by using the formula, $r = (1 + R)/(1 + \pi) - 1$, where r is the real interest rate, R is the nominal interest rate and π is the inflation rate measured by the annual percentage change in GDP deflator. To identify the system, we use Cholesky decomposition, ordering the variables as GDP, consumption, housing prices, bank capital, the lending rate and bank credit.

We study the role of a bank capital shock in our empirical analysis for two reasons. First, the bank capital constraint (that ties bank lending to bank capital) plays a critical role in the transmission channel through which the banking sector interacts with the real sector. Second, since the macroprudential instrument (in this case, the capital requirement ratio) works to restrain or free banks' own available resources for lending, establishing the impact of bank capital on bank lending is also key in understanding the implications of capital requirements and the link between the financial sector and the real economy. A negative bank capital shock serves as a proxy for loan repayment shock, corresponding to unexpected increase in loan losses. In effect, unexpected increase in loan losses leads to a decline in banks' profits (retained earnings), and ultimately erodes bank capital.

Figure 3 shows the impulse responses of the variables following a negative bank capital shock. Consistent with the literature (see for e.g., Berrospide and Edge; 2010, Michelangeli and Sette; 2016, Mésonnier and Stevanovic; 2017, Kanngiesser et al.; 2017), the results show that a negative bank capital shock curtails bank lending and leads to a fall in housing prices, consumption and output. Although these studies use different measures of bank capital (e.g., the capital-asset ratio), they establish that a negative bank capital shock induces banks to shrink their balance sheets and curtail credit with negative implications for real economic activity. The results suggest a negative relationship between banks' net worth (capital) and lending rates, and provide further evidence regarding the co-movements between bank capital, bank lending, housing prices, consumption and output observed in figures 1 and 2.

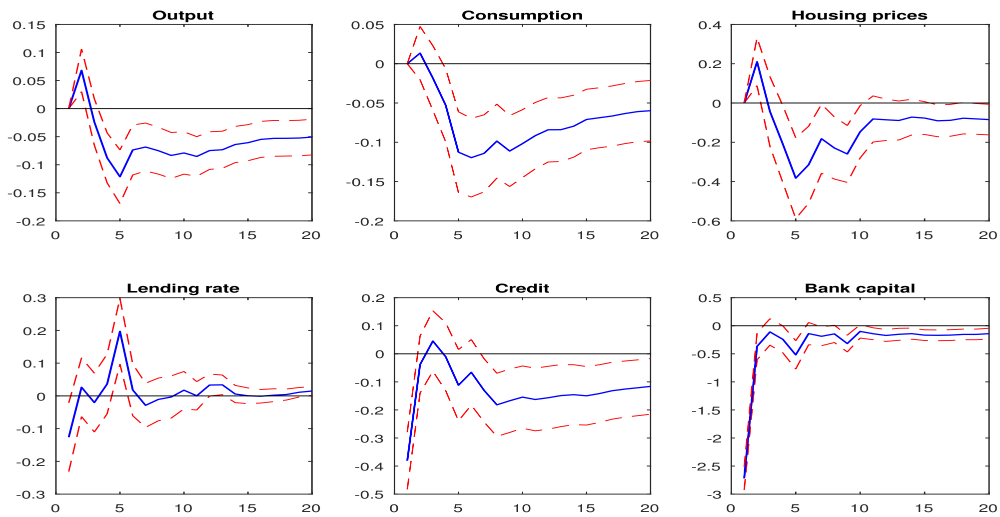

Figure 3: VAR impulse responses to a negative shock on bank capital. Note: red dashed lines represent one standard error bands.

Figure 4 shows the impulse responses of the variables following a positive shock on housing prices. The shock results in an increase in bank credit, consumption and output. The same is also true for bank capital. The shock causes a temporary increase in the lending rate with the impact becoming negative 4 quarters after the shock occurs. In general, the results suggest that a positive shock on housing prices has an expansionary impact on bank credit, consumption and output. These findings are consistent with the findings in the SA literature (see e.g., Aye et al.; 2014, Apergis et al.; 2014) and confirm the co-movement between housing prices, bank lending, consumption and output highlighted in figures 1 and 2.

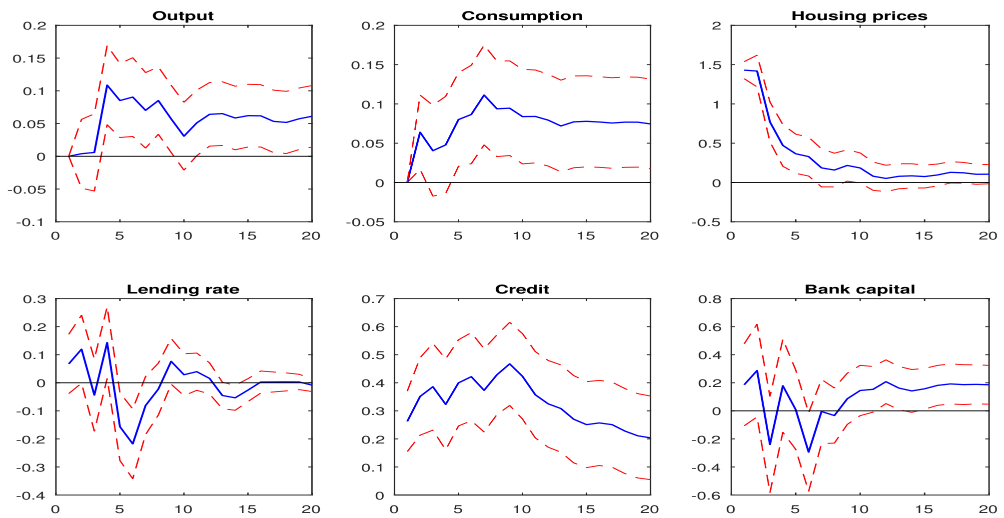

Figure 4: VAR impulse responses to a positive shock on housing prices. Note: red dashed lines represent one standard error bands.

3 The model

The model framework is a closed economy real business cycle model featuring a banking sector, financial frictions and a macroprudential authority. Specifically, the model is built on the workhorse of Iacoviello (2005, 2015) and incorporates the role of a macroprudential authority in accordance with Basel capital regulatory frameworks following Angelini et al. (2014) and Rubio and Carrasco-Gallego (2016). In contrast to monetary business cycle models, the model abstracts from nominal rigidities. We keep the model simple enough and sufficient to provide insights on how counter-cyclical capital requirements contribute to financial and macroeconomic stability.

In this section, we first present the baseline model and lay out the transmission mechanisms through which technology, housing demand and loan repayment shocks affect the financial sector and the real economy and the role of bank capital requirements. The baseline model features three agents: households, entrepreneurs and financial intermediaries (bankers). In this setup, we assume that households are the net savers in the economy while entrepreneurs are the net borrowers. In the subsequent section, we extend the baseline model and relax this assumption. Specifically, we introduce heterogeneity in the household sector and allow one group of households to be savers and the other to be borrowers. This helps us to capture some of the salient features of the SA's economy highlighted in subsection 2.1 and affords a more realistic analysis of SA's housing market and mortgage credit market.

3.1 The baseline model

The model economy is populated by households, entrepreneurs and bankers. Households consume final output and housing services, and supply labour to entrepreneurs. They are net savers in the economy and provide banks with funds in the form of savings deposits which earn a risk-free return. Entrepreneurs produce final output using labour and commercial real estate as inputs. To finance their production, entrepreneurs borrow funds from financial intermediaries against their stock of housing wealth. Bankers accept savings deposits from households (savers) and provide credit to entrepreneurs (borrowers). Bankers are subject to a risk-weighted capital requirement. The macroprudential authority is responsible for setting bank capital requirements in line with Basel capital regulations.

3.1.1 Households

The representative household chooses real consumption ($C_{s,t}$), residential real estate or housing services ($H_{s,t}$) and leisure (1 - N_t) to maximize the expected discounted lifetime utility function:

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

where E_0 and $\beta_s \in (0,1)$ denote the expectation operator and household's subjective discount factor, respectively. η_s measures the degree of habit persistence for consumption. 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 the habit parameter in the steady state. j and τ are the weights of housing and leisure in the utility function, respectively. A_t denotes a housing demand shock that evolves according to the following law of motion:

$$log(A_t) = \rho_a log(A_{t-1}) + \xi_{a,t}, \quad 0 < \rho_a < 1, \tag{2}$$

where ρ_a is the persistence parameter of the shock process. $\xi_{a,t} \sim i.i.d.N(0, \sigma_a^2)$ is the white noise process, normally distributed with mean zero and variance σ_a^2. The housing demand shock captures exogenous factors which can shift households' preference and demand for housing. Iacoviello (2005) suggests that the housing demand shock offers a parsimonious way to analyse exogenous disturbances on housing prices.

In each period, the household begins with housing stock ($H_{s,t-1}$) and savings deposits (D_{t-1}) coming to maturity. Households also supply labour to entrepreneurs and receive a real wage rate W_t. Let $R_{d,t}$ denote the real gross return on one-period risk-free deposits and q_t denote the relative price of real estate (in units of consumption), the household's budget constraint is given by:

$$C_{s,t} + D_t + q_t(H_{s,t} - H_{s,t-1}) = W_t N_t + R_{d,t-1} D_{t-1}, \tag{3}$$

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 for households' problem are as follows:

$$1 = \beta_s E_t \frac{U_{Cs,t+1}}{U_{Cs,t}} R_{d,t}, \tag{4}$$

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

$$W_t = \frac{\tau}{(1-N_t) U_{Cs,t}}. \tag{6}$$

Equation 4 is the standard consumption Euler equation. Asset pricing equation (5) for real estate equates the marginal cost of housing to its marginal benefit. For households, the marginal benefit of housing is given by the direct utility benefit of consuming one extra unit of real estate service in units of consumption (marginal rate of substitution between real estate and consumption) plus the present discounted value of housing (benefit housing provides in the next period as a store of wealth). Equation 5 can also be regarded as households' demand function for housing. Labour supply condition (6) equates the real wage rate to the marginal rate of substitution between consumption and leisure.

3.1.2 Entrepreneurs

Entrepreneurs produce final output (Y_t) using labour (N_t) and commercial real estate ($H_{e,t}$) as inputs. Commercial real estate includes retail, office and industrial properties. The representative entrepreneur maximizes her expected lifetime utility function:

$$E_0 \sum_{t=0}^{\infty} \beta_e^t (1-\eta_e) log(C_{e,t} - \eta_e C_{e,t-1}), \tag{7}$$

where $\beta_e < \beta_s$ and $C_{e,t}$ is the entrepreneur's real consumption. Since entrepreneurs are the owners of firms, their consumption can be regarded as profits or dividends payout. As such, $\eta_e C_{e,t-1}$ 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 to adequately explain the dynamics between asset prices and real variables. The budget constraint of the entrepreneur is given by:

$$C_{e,t} + q_t(H_{e,t} - H_{e,t-1}) + R_{e,t}L_{e,t-1} + W_t N_t + AC_{le,t} = Y_t + L_{e,t} + \zeta_{e,t}, \tag{8}$$

where $L_{e,t}$ is the amount of loans borrowed from bankers which accrue real gross interest rate of $R_{e,t}$. $AC_{le,t} = \frac{\phi_{le}}{2}\frac{(L_{e,t}-L_{e,t-1})^2}{L_e}$ is the quadratic loan portfolio adjustment cost, where L_e is the steady-state value of $L_{e,t}$. This cost penalizes entrepreneurs for adjusting their loan portfolios rapidly between periods.

Following Iacoviello (2015), we introduce an exogenous loan repayment shock $\zeta_{e,t}$. Intuitively, the loan repayment shock can be thought of as unexpected increase in loan losses when borrowers fail to honour their financial contracts. The shock represents an income gain (increase in wealth) for borrowers. This is because by paying less than the contractual amount of loans, borrowers are able to spend more than previously anticipated. The same shock appears on the liability side of financial intermediaries' balance sheet, but with a negative sign. For financial intermediaries, this represents losses that bankers incur when borrowers fail to honour their contractual obligations. The shock evolves according to the following law of motion:

$$\zeta_{e,t} = \rho_\zeta \zeta_{e,t-1} + \xi_{\zeta,t}, \quad 0 < \rho_\zeta < 1, \tag{9}$$

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

Entrepreneurs also face the borrowing constraint:

$$L_{e,t} \leq m_e E_t \left(\frac{q_{t+1}}{R_{e,t+1}} H_{e,t} \right). \tag{10}$$

Equation 10 suggests that the total amount of credit entrepreneurs can secure from bankers cannot exceed a fraction m_e of the expected market value of their collateral assets. m_e can be regarded as loan-to-value ratio associated to real estate. The dual role of commercial real estate as collateral asset and productive input is widely acknowledged in DSGE literature (see for e.g., Iacoviello; 2005, Chaney et al.; 2012, Liu et al.; 2013, Minetti and Peng; 2013). As will be shown later, the condition $\beta_e < \beta_s$ ensures that the borrowing constraint (10) is binding in the neighbourhoods of the steady state.

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 (10), the first order conditions which define entrepreneurs' problem are as follows:

$$q_t = \beta_e E_t \frac{U_{Ce,t+1}}{U_{Ce,t}} \left(\alpha \frac{Y_{t+1}}{H_{e,t}} + q_{t+1} \right) + m_e(\lambda_{e,t}/U_{Ce,t}) E_t \frac{q_{t+1}}{R_{e,t+1}}, \tag{11}$$

$$W_t N_t = (1-\nu) Y_t, \tag{12}$$

$$1 - \frac{\phi_{le}}{L_e}(L_{e,t} - L_{e,t-1}) = \lambda_{e,t}/U_{Ce,t} + \beta_e E_t \frac{U_{Ce,t+1}}{U_{Ce,t}} R_{e,t+1}. \tag{13}$$

Equation 11 represents entrepreneurs' demand function for housing. It equates the marginal cost of one extra unit of real estate (current price of real estate) to its marginal benefits. For entrepreneurs, the marginal benefit of housing is given by the present discounted value of the next period's real return on commercial real estate plus the benefit of real estate as a collateral asset for securing credit. Entrepreneurs' real return on real estate is given by the marginal product of real estate and future resale value of real estate. Equation 12 is the labour demand condition. Equation 13 is the asset pricing equation for borrowing.

Production technology is given by a constant-return to scale Cobb-Douglas production function:

$$Y_t = Z_t H_{e,t-1}^{\nu} N_t^{1-\nu}, \tag{14}$$

where the parameter $\nu \in (0,1)$ is the elasticity of output with respect to commercial real estate. A technology shock (Z_t) evolves according to the following law of motion:

$$log(Z_t) = \rho_z log(Z_{t-1}) + \xi_{z,t}, \quad 0 < \rho_z < 1, \tag{15}$$

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

3.1.3 Financial intermediaries

Financial intermediaries (bankers) intermediate funds between savers (households) and borrowers (entrepreneurs). The representative banker chooses real consumption ($C_{f,t}$) to maximize the expected lifetime utility function:

$$E_0 \sum_{t=0}^{\infty} \beta_f^t (1-\eta_f) log(C_{f,t} - \eta_f C_{f,t-1}), \tag{16}$$

where β_f denotes the banker's subjective discount factor. Note that $C_{f,t}$ can be interpreted as dividend payments from bankers, which are assumed to be fully consumed by themselves (as owners). $\eta_f C_{f,t-1}$ represents some form of dividend smoothing. Bankers' budget constraint is given by:

$$C_{f,t} + R_{d,t-1} D_{t-1} + L_{e,t} + AC_{ef,t} = D_t + R_{e,t} L_{e,t-1} - \zeta_t, \tag{17}$$

where D_t denotes households deposits, $L_{e,t}$ is credit extended to entrepreneurs. $AC_{ef,t} = \frac{\phi_{ef}}{2}\frac{(L_{e,t}-L_{e,t-1})^2}{L_e}$ is the quadratic loan adjustment cost, reflecting costs associated with monitoring and redeeming existing loans and granting new ones, etc. ζ_t is the loan repayment shock that represents unexpected loan losses. From bankers' perspective, loan losses represent a shock on their capital positions (bank net worth). An increase in loan losses reduces banks' profits and impairs their balance sheets. This results in a decline in bank capital. That said, the loan repayment shock can be regarded as a shock on bank capital.

Financial intermediaries are subject to a capital requirement constraint in line with Basel capital regulations. Specifically, banks are required to hold a certain amount of bank capital that covers, at least, a specified fraction of their assets (loans). SA banks consistently maintain capital adequacy ratios over the regulatory requirements. Over the period 2008 - 2015, the average amount of bank capital held by SA banks is approximately 12 % of risk weighted assets. For simplicity, the paper does not distinguish between required capital and excess capital held voluntarily by SA banks.

Let bank capital be $BK_t = L_{e,t} - D_t - E_t\zeta_{t+1}$, the capital adequacy constraint is given by:

$$\frac{L_{e,t} - D_t - E_t\zeta_{t+1}}{L_{e,t} - E_t\zeta_{t+1}} \geq \kappa_t, \tag{18}$$

where κ_t is the capital adequacy ratio (CAR). The capital adequacy constraint (18) can be rewritten and re-interpreted as a borrowing constraint as follows:

$$D_t \leq (1-\kappa_t)(L_{e,t} - E_t\zeta_{t+1}). \tag{19}$$

Equation 19 states that the amount of deposits that bankers can take cannot exceed a fraction $(1-\kappa_t)$ of bankers' assets net off the expected loan losses. The assumption $\beta_f < \beta_s$ ensures that the constraint (19) is binding in the steady state. In the absence of this assumption, bankers may find that it is optimal to postpone current consumption indefinitely and accumulate capital (through increasing in retained earnings) 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 capital adequacy constraint, the bank's optimal conditions for deposits and credit are given by:

$$1 - \lambda_{f,t}/U_{Cf,t} = \beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} R_{d,t}, \tag{20}$$

$$\beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} R_{e,t+1} = 1 - (\lambda_{f,t}/U_{Cf,t})(1-\kappa_t) + \frac{\phi_{ef}}{L_e}(L_{e,t} - L_{e,t-1}). \tag{21}$$

The bankers' behavioural rule for taking deposits (20) suggests that the current period pay-off from taking one extra unit of deposit from households should equal the present discounted cost of raising such deposits from households. Equation 21 equates the present discounted pay-off of providing one extra unit of credit to the marginal cost of providing such credit. It suggests that by reducing the pay-off, through reduction in credit and tightening the capital requirement constraint, bankers can reduce next period's marginal cost of credit extension (in terms of forgone interest earning per unit of loan). $\lambda_{f,t}/U_{Cf,t}$ is the utility cost of tightening the capital requirement constraint through credit reduction.

From equations 20 and 21, the evaluation of the interest rate differential is given by:

$$R_{e,t+1} - R_{d,t} = \frac{1}{\beta_f} E_t \frac{U_{Cf,t}}{U_{Cf,t+1}} \left[\kappa_t (\lambda_{f,t}/U_{Cf,t}) + \frac{\phi_{ef}}{L_e} (L_{e,t} - L_{e,t-1}) \right]. \tag{22}$$

Aside from portfolio adjustment costs, this condition implies that the presence of bank capital regulation creates a wedge between the lending rate and the deposit rate (marginal cost of funding in this case). In the absence of equity financing, bankers need to accumulate retained earnings to meet higher regulatory requirement. As such, a high capital requirement creates incentive for bankers to increase the credit spread and boost profits to meet the tighter regulatory requirement. Intuitively, equation 22 implies that bankers pass the cost of capital regulation onto borrowers by requiring high compensation as the regulatory requirement becomes tighter.

Combining the steady state conditions of (4) and (20), we have

$$\lambda_f / U_{Cf} = \frac{\beta_s - \beta_f}{\beta_s} > 0. \tag{23}$$

That is, so long as bankers are more impatient than households ($\beta_f < \beta_s$), the borrowing constraint and the capital requirement constraint hold with equality at the steady state. Furthermore, with $0 < \kappa < 1$, in steady state the spread between the lending rate and the deposit rate is positive:

$$R_e - R_d = \frac{1}{\beta_f} (\lambda_f / U_{Cf}) \kappa > 0. \tag{24}$$

Using equations 13, 21 and 23, the necessary condition for entrepreneurs' borrowing constraint to hold with equality is given by:

$$\frac{1}{\beta_e} > (1 - \kappa) \frac{1}{\beta_s} + \kappa \frac{1}{\beta_f}. \tag{25}$$

This implies that $\beta_s > \beta_f > \beta_e$.

3.1.4 Macroprudential policy

Following Angelini et al. (2014), macroprudential policy is defined as follows:

$$\kappa_t = \kappa \left(\frac{X_t}{X} \right)^{\chi_x}, \tag{26}$$

where, κ is the steady state value of the capital adequacy ratio in accordance with the Basel capital regulation. X_t and X are the credit-to-output ratio and its steady-state value, respectively. The parameter χ_x measures policy response to changes in credit-to-output gap, proposed by the Bank for International Settlements (BCBS; 2009).[5]

Equation 26 can be regarded as a general specification for Basel capital regulation regimes since different values of χ_x correspond to different regimes of the bank capital regulation. $\chi_x = 0$ represents the case of fixed capital requirement ratio under Basel I. A negative value of χ_x corresponds to the pro-cyclical Basel II, that is, the capital requirement ratio decreases in the upswing of business cycle and increases in the downswing. Lastly, setting $\chi_x > 0$, equation 26 represents the leaning-against-the-wind policy of the Basel III counter-cyclical capital buffer – promoting the build-up of capital buffers in good times, which can then be released in bad times.

[5] In the optimal policy analysis, we will consider alternative policy rules with different indicators.

3.1.5 Market clearing conditions and equilibrium

The economy's aggregate resource constraint is given by:

$$Y_t = C_{s,t} + C_{e,t} + C_{f,t} + Adj_t, \tag{27}$$

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

The housing market clearing condition requires:

$$H_{s,t} + H_{e,t} = 1, \tag{28}$$

where the total supply of real estate is fixed and normalised to one.

3.2 The extended model

To gain more insight into the implications of Basel III and capture some of the salient features of the SA economy as highlighted in 2.1, we extend the baseline model by introducing household borrowers in the household sector. Impatient households use their housing wealth as collateral assets to secure credit from financial intermediaries. The problem of patient households remains unchanged. This extension accommodates the fact that, over the period 1994 - 2016, the average share of household mortgage loans in total mortgage loans is approximately 77 percent.[6] It is, therefore, more realistic to have household borrowers in the model. In addition, there is growing evidence that housing prices are important in explaining household consumption in SA (e.g., Apergis et al.; 2014, Aye et al.; 2014).

For the sake of brevity, the section only lays out additional features of the extended model: the problem of household borrowers and the modified parts of the model for entrepreneurs and financial intermediaries. The complete set of equations (including the first order conditions) for the extended version of the model is presented in appendix II.

3.2.1 Impatient Households (Borrowers)

Analogous to patient households, impatient households maximize the present discounted value of the lifetime utility function:

$$E_0 \sum_{t=0}^{\infty} \beta_b^t \Big[(1-\eta_b) log(C_{b,t} - \eta_b C_{b,t-1}) + jA_t log(H_{b,t}) + \tau log(1-N_{b,t}) \Big], \tag{29}$$

where β_b is impatient households' subjective discount factor, and $\beta_b < \beta_s$. $C_{b,t}$ denotes real consumption, $H_{b,t}$ is residential real estate holding and $N_{b,t}$ denotes impatient households' labour supply. Their budget constraint is given by;

$$C_{b,t} + R_{b,t-1}L_{b,t-1} + q_t(H_{b,t} - H_{b,t-1}) + AC_{lb,t} = W_{b,t}N_{b,t} + L_{b,t} + \zeta_{b,t}, \tag{30}$$

where $L_{b,t}$ represents loans to impatient households which accrue a real gross interest rate of $R_{b,t}$. $W_{b,t}$ is the real wage rate for impatient households. $AC_{lb,t} = \frac{\phi_{lb}}{2}\frac{(L_{b,t} - L_{b,t-1})^2}{L_s}$ is the loan portfolio adjustment

[6] The average share of household credit (mortgage loans plus other loans and advances) in total private sector credit from commercial banks is approximately 52 percent over the period 1994-2016.

cost, assumed to be external to impatient households. ϕ_{lb} denotes the adjustment cost parameter, whereas L_e is the steady-state value of $L_{e,t}$. $\zeta_{b,t}$ is a household loan repayment shock that represents an indirect income gain (increase in wealth) for household borrowers in the event of loan default.

Analogous to entrepreneurs, impatient households also face a credit constraint that limits the amount of borrowing to a fraction m_b of the expected value of real estate holdings:

$$L_{b,t} \leq m_b E_t \left(\frac{q_{t+1}}{R_{b,t}} H_{b,t} \right). \tag{31}$$

3.2.2 Entrepreneurs

Entrepreneurs maximize the expected lifetime utility function,

$$E_0 \sum_{t=0}^{\infty} \beta_e^t (1-\eta_e) log(C_{e,t} - \eta_e C_{e,t-1}). \tag{32}$$

The budget constraint for entrepreneurs is now given by:

$$C_{e,t} + q_t(H_{e,t} - H_{e,t-1}) + R_{e,t}L_{e,t-1} + W_{s,t}N_{s,t} + W_{b,t}N_{b,t} + AC_{le,t} = Y_t + L_{e,t} + \zeta_{e,t}, \tag{33}$$

where $N_{s,t}$ and $N_{b,t}$ are patient and impatient households' labour supply, respectively.

Production technology (14) becomes:

$$Y_t = Z_t H_{e,t-1}^{\nu} [N_{s,t}^{1-\sigma} N_{b,t}^{\sigma}]^{1-\nu}, \tag{34}$$

where $\sigma \in (0, 1)$ measures the share of impatient households labour income.

3.2.3 Financial intermediaries

Financial intermediaries maximize the expected lifetime utility function:

$$E_0 \sum_{t=0}^{\infty} \beta_f^t (1-\eta_f) log(C_{f,t} - \eta_f C_{f,t-1}). \tag{35}$$

The budget constraint (17) becomes:

$$C_{f,t} + R_{d,t-1}D_{t-1} + L_{b,t} + L_{e,t} + AC_{bf,t} + AC_{ef,t} = D_t + R_{b,t-1}L_{b,t-1} + R_{e,t}L_{e,t-1} - \zeta_t, \tag{36}$$

where $L_{b,t}$ and $L_{e,t}$ are bank lending 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. $\zeta_t = \zeta_{b,t} + \zeta_{e,t}$ is the loan repayment shock that represents loan losses that banks incur when household borrowers and entrepreneurs default. Let bank capital be $BK_t = L_t - D_t - E_t\zeta_{t+1}$, the capital adequacy constraint is given by:

$$\frac{L_t - D_t - \zeta_{t+1}}{w_b L_{b,t} + w_e L_{e,t} - E_t \zeta_{t+1}} \geq \kappa_t, \tag{37}$$

where $L_t = L_{b,t} + L_{e,t}$ is the total credit. w_b and w_e capture different degrees of risk associated with household and entrepreneur loans, respectively. The capital adequacy constraint (37) can be rewritten as a borrowing constraint as follows:

$$D_t \leq (1 - w_e \kappa_t)(L_{e,t} - E_t \zeta_{e,t+1}) + (1 - w_b \kappa_t)(L_{b,t} - E_t \zeta_{b,t+1}). \tag{38}$$

3.2.4 Market clearing conditions

The economy's aggregate resource constraint becomes;

$$Y_t = C_{s,t} + C_{b,t} + C_{e,t} + C_{f,t} + Adj_t, \tag{39}$$

where $Adj_t = \sum AC_{ij,t}$. Aggregate resource constraint shows that final output is consumed and used to finance adjustment costs.

The housing market clearing condition requires:

$$H_{s,t} + H_{b,t} + H_{e,t} = 1. \tag{40}$$

The total supply of credit is given by:

$$L_t = L_{b,t} + L_{e,t}. \tag{41}$$

4 Calibration

We calibrate the model to the SA economy over the sample period 1994Q1 - 2016Q4. Some of the parameters are calibrated using the real data to match steady state conditions of the model, while others are borrowed from the DSGE literature for EMEs.

Table 1 reports the calibrated parameter values for both the baseline and extended models. The discount factor for patient household (savers) is set at $\beta_s = 0.991$ to match the SA average real deposit rate of 3.5 percent (annualized) over the sample period. Following Iacoviello (2015), impatient households' and entrepreneurs' discount factors are calibrated at $\beta_b = \beta_e = 0.94$. The discount factor for financial intermediaries is set at $\beta_f = 0.95$, which is lower than savers' discount factor (β_s) and higher than those of household borrowers and entrepreneurs. Discount factors are calibrated such that condition (25) holds: both impatient households' and entrepreneurs' borrowing constraints and capital adequacy constraint are binding in the neighbourhood of steady state.[7] The calibrated discount factors imply a spread of 200 basis points between the lending rate and the deposit rate, which is broadly in line with SA's interest rate data. For the parameter governing the macroprudential policy rule, we set $\chi_x = -0.5$ to mimic the pro-cyclical Basel II regime. For the Basel III regime, we reverse the sign of χ_x to mimic the counter-cyclical buffer.

The share of housing (commercial real estate) in production is set at $\nu = 0.1$ in the ballpark of the values widely used in the literature for EMEs (e.g., Iacoviello and Minetti; 2006). The housing weight in the utility functions is calibrated at $j = 0.1$. The choice of these values pins down the steady state ratio of real estate wealth to output at 3.0 (annualized), of which 2.2 is residential real estate wealth and 0.8 is commercial real estate wealth. These ratios are fairly in line with the SA data on housing wealth.[8]

[7] See section 3.1.3 for a detailed discussion on the conditions for the capital adequacy constraint is binding in the steady state.

[8] The 2016 Property Sector Charter Council's (PSCC) report suggests that the share of SA real estate wealth to total output is approximately 2.3, 75 percent of which constituted residential real estate wealth while the remaining is commercial real estate. Source: http://www.sacommercialpropnews.co.za/property-investment/8211-sa-property-sector-volumes-to-r5-8-trillion.html.

Table 1: Calibrated parameters.

Description	Parameter	Value	
		Baseline model	Extended model
Patient household discount factor	β_s	0.991	0.991
Impatient household discount factor	β_b	-	0.94
Entrepreneur discount factor	β_e	0.94	0.94
Banker discount factor	β_f	0.95	0.95
Habit persistence	η_i	0.70	0.70
Impatient household LTV ratio	m_b	-	0.90
Entrepreneur LTV ratio	m_e	0.70	0.70
Housing preference	j	0.10	0.10
Utility parameter for labor supply	τ	2.0	2.0
Housing share in production	ν	0.10	0.10
Impatient household income share	σ	-	0.31
Impatient household borrowing Adj. cost	ϕ_{lb}	-	0.05
Entrepreneur borrowing Adj. cost	ϕ_{le}	0.05	0.05
Bankers' loans to household Adj. cost	ϕ_{bf}	-	0.10
Bankers' loans to entrepreneurs Adj. cost	ϕ_{ef}	0.10	0.10
Risk weight (impatient household lending)	w_b	-	1.00
Risk weight (entrepreneurs lending)	w_e	-	1.00
Basel II CAR	κ_{II}	0.08	0.08
Basel II.5 & III CAR	κ_{III}	0.105	0.105
Autocorr. technology shock	ρ_z	0.9	0.9
Autocorr. housing demand shock	ρ_a	0.8	0.8
Autocorr. entrepreneur loan repayment shock	ρ_{ζ_e}	0.9	0.9
Autocorr. household borrower loan repayment shock	ρ_{ζ_b}	-	0.9

Leverage ratios for impatient households and entrepreneurs are set based on credit market data over the sample period. The loan-to-value (LTV) ratio for impatient households is set at $m_b = 0.9$. This value is fairly consistent with the minimum down-payment that SA banks require for providing home loans. In the case of entrepreneurs, LTV is set at $m_e = 0.7$. In the steady state, the ratio of household mortgage loans to total output is approximately 0.35, while the ratio of corporate credit to output is 0.53. Bankers' leverage ratio is set to mimic Basel bank capital requirements, which is explained in section 6. The risk weights assigned to household and entrepreneur loans are both set at $w_b = w_e = 1$.

The weight on leisure in households' utility function τ is set at 2, implying that households spend approximately one third of their time working. The impatient households' labour income share is calibrated at $\sigma = 0.31$, broadly in line with the estimated value of 0.27 in Gupta and Sun (2016) for the SA economy. Habit persistence for all agents is set at $\eta = 0.7$, which is broadly in line with the literature. Impatient households' and entrepreneurs' loan portfolio adjustment cost parameters are set at $\phi_{lb} = \phi_{le} = 0.05$. For financial intermediaries, these parameters are calibrated at $\phi_{bf} = \phi_{ef} = 0.10$.

Lastly, for the housing demand shock, the autocorrelation coefficient is set at 0.8, while the persistence of technology and loan repayment shocks is set at 0.9 based on the estimates of Iacoviello (2015).

5 Business cycle properties

This section assesses the business cycle properties of the baseline and extended models. Table 2 reports standard deviations of the main variables and their correlations with output implied by the baseline and extended models and those calculated from the actual data. For the model, the second moments are generated from a 1 percent productivity shock under the two Basel regimes.

Table 2: Business cycle properties.

Variable	Standard deviation (%)					Correlation with output				
	Data	Baseline model		Extended model		Data	Baseline model		Extended model	
		Basel II	Basel III	Basel II	Basel III		Basel II	Basel III	Basel II	Basel III
Output	1.16	1.29	1.23	1.11	1.06	1.00	1.00	1.00	1.00	1.00
Household consumption	1.76	1.18	1.12	1.09	1.03	0.81	0.99	0.99	0.99	0.99
House prices	4.59	2.00	1.89	1.60	1.53	0.30	0.80	0.80	0.89	0.89
Household deposits	2.77	5.84	4.46	4.38	3.26	0.23	0.86	0.88	0.86	0.91
Household loans	4.08	-	-	5.42	4.76	0.51	-	-	0.85	0.89
Corporate loans	4.81	5.64	4.67	3.58	2.67	0.31	0.82	0.83	0.88	0.91
Lending rate	0.83	0.42	0.67	0.58	0.77	-0.16	-0.50	-0.33	-0.11	-0.09

Data over 1994Q1 – 2016Q4 are obtained from the SARB. With the exception of lending rate, all variables are log-transformed and de-trended using HP filter.

The results show that the baseline and extended models reproduce the cyclical moments of the real sector fairly well. Standard deviations of output generated from both models are fairly close to the one observed from the data. The two models also do a reasonably good job in matching the standard deviation of consumption, but underestimate it to a certain extent. Both models underestimate the standard deviation of housing prices, and this is particularly so for the extended model.

Both the baseline and the extended models reproduce variability of the lending rate which is fairly in line with the data, especially under Basel III. Though the baseline model somewhat exaggerates the volatility of deposits, the extended model reproduces it well in line with the data. This is particularly so under Basel III. The baseline model does a good job in replicating the standard deviation of corporate loans, whereas the model under Basel II slightly overestimates and the model under Basel III slightly underestimates it. The extended model also performs well in replicating standard deviations of household and corporate loans. Both the baseline and the extended models reproduce the fact that consumption, housing prices, deposits and loans are more volatile than output, whereas the lending rate is less volatile than output.

The results further show that the baseline and extended models reproduce the co-movements between output and the main variables, which are fairly consistent with the data. Both models predict the positive correlation of output with consumption, housing prices, deposits and loans, but overestimate these positive correlations. The baseline and the extended models also do a fairly good job in mimicking the negative correlation between the lending rate and output. While the extended model reproduces the negative correlation which is fairly in line with the data, the baseline model somewhat overestimates this negative correlation.

6 Pro-cyclical effects of Basel regimes: Basel II vs. Basel III

In this section, we compare the pro-cyclical effects of Basel II and III by studying the impulse responses of the key macroeconomic and financial variables following technology, loan repayment, and housing demand shocks.[9] The transition from Basel II to Basel III capital requirement regime can be decomposed into two stages. The first stage entails a permanent increase in the capital adequacy ratio from 8 % to 10.5 %, in line with the conservative capital buffer. The second stage involves the introduction of a counter-cyclical capital buffer – the dynamic component of Basel III bank capital requirements.

To illustrate this transitional effect we compare model dynamics under the three regulatory regimes following positive productivity, loan repayment and housing demand shocks. The first regime corresponds to the Basel II capital requirement defined by $\kappa = 0.08$ and $\chi_x < 0$. The second regime corresponds to the Basel II capital requirement plus the capital conservation buffer of 0.025, that is, $\kappa = 0.105$ and $\chi_x < 0$. This can be regarded as the first stage of the transition from Basel II to Basel III and is referred to as Basel II.5. The third regime corresponds to the full implementation of Basel III, defined by setting $\kappa = 0.105$ and $\chi_x > 0$.

6.1 Productivity shock

We first consider the impact of a positive productivity shock and analyse the dynamics of the model under the three Basel regimes: Basel II, Basel II.5 and Basel III. Figure 5 presents the impulse responses of the main variables following the shock. The real shock leads to an increase in entrepreneurs' demand for commercial real estate, as they take advantage of higher technology. This triggers an increase in housing prices, which, in turn, increases entrepreneurs' net worth and borrowing capacity. As the marginal value of collateral assets increases, entrepreneurs can borrow more and increase production. With the increasing demand for credit, the cost of borrowing (interest rate spread) also rises. Consumption for all agents also increases.

Under the Basel II regime, as the economy enters into a boom (credit-to-GDP ratio increases), the risk-weighted bank capital requirement falls – the regulatory requirement is relaxed. This creates scope for bankers to extend more credit. The relaxed capital requirement exacerbates the initial impact of the shock on financial and business cycles.

The transition from Basel II to Basel III attenuates the pro-cyclical effects of the Basel II capital regulation framework. With the decomposition analysis of the transition to Basel III, we are able to identify that it is the counter-cyclical capital buffer that significantly mitigates the pro-cyclical effects of Basel II, whereas the attenuation effect of the conservation buffer (Basel II.5) is marginal. Under the Basel III regime, the macroprudential authority increases CAR when the credit-to-GDP ratio increases. To meet the higher regulatory requirement, bankers have to adjust their balance sheet by either increasing capital (by increasing retained earnings and reducing consumption) or reducing lending. Since bankers are relatively impatient, the feasible option for them is to cut back on lending. Under Basel III, the

[9] Here we report the results for the baseline model only, whereas the results for the extended model are reported in appendix D.

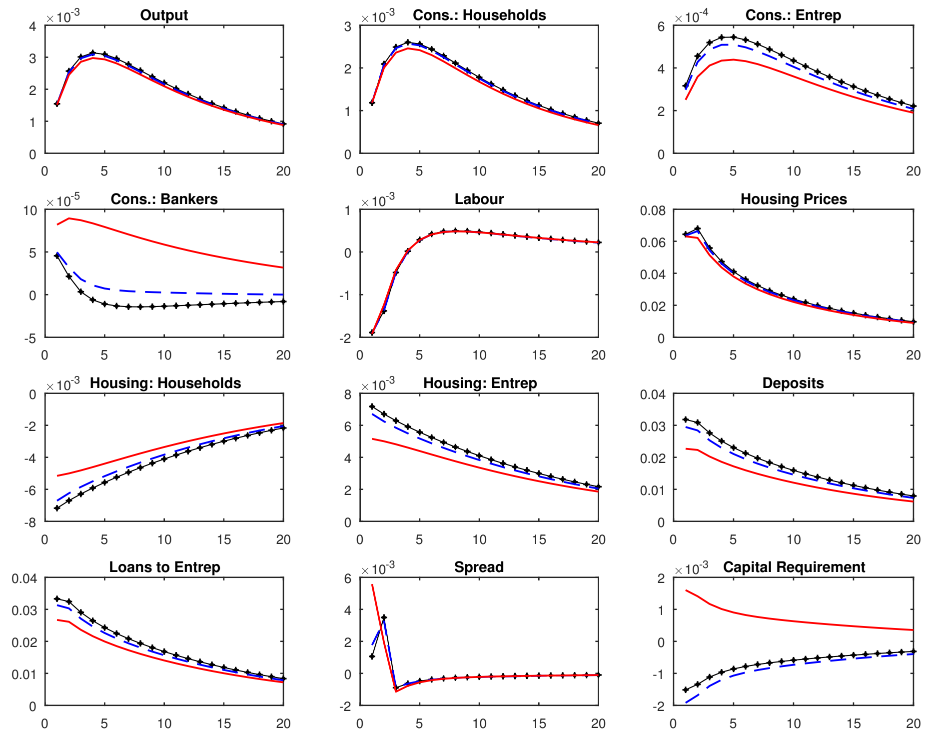

Figure 5: Impulse responses to a positive productivity shock under alternative Basel regimes. Notes: Black asterisk line: Basel II; Blue dashed line: Basel II.5; Red solid line: Basel III. Variables are expressed in % deviations from steady states, and interest rates are in percentage points.

lending rate (interest rate spread) increases further in response to the shock and this further curtails credit growth. This, in turn, reduces the extent of the increase in housing prices, which has a feedback effect on the market value of borrowers' collateral and results in a further decrease in the demand for credit. This attenuation effect passes onto the real economy, mitigating business cycle fluctuations.

In summary, the results show that Basel III is more effective in attenuating fluctuations in financial variables and has potential to deliver a more stable financial system. Nevertheless, the impact of Basel III on fluctuations in real variables (particularly, output and aggregate consumption[10]) is negligible in the case of a productivity shock.

6.2 Loan repayment shock

Figure 6 shows the impulse responses of the main variables to a negative loan repayment shock (corresponding to an unexpected increase in loan losses). The shock reduces bankers' net worth, which forces bankers to consume less. To meet the required CAR bankers have to reduce lending. With falling credit, entrepreneurs' demand for housing declines, causing a fall in housing prices. Consequently, output and household consumption decrease while entrepreneur consumption increases. The increase in entrepreneur consumption is due to the income gain as the consequence of default. The associated increase in the

[10]Measured as the sum of households', entrepreneurs' and bankers' consumption. That is, $C_t = C_{s,t} + C_{e,t} + C_{f,t}$.

lending rate (interest rates spread) curtails borrowing and restrains consumption and output. These results concur with the finding by Iacoviello (2015) that a negative loan repayment shock has recessionary effects. Furthermore, the results conform with the VAR evidence on the impact of a negative shock on bank capital (see sub-section 2.2).

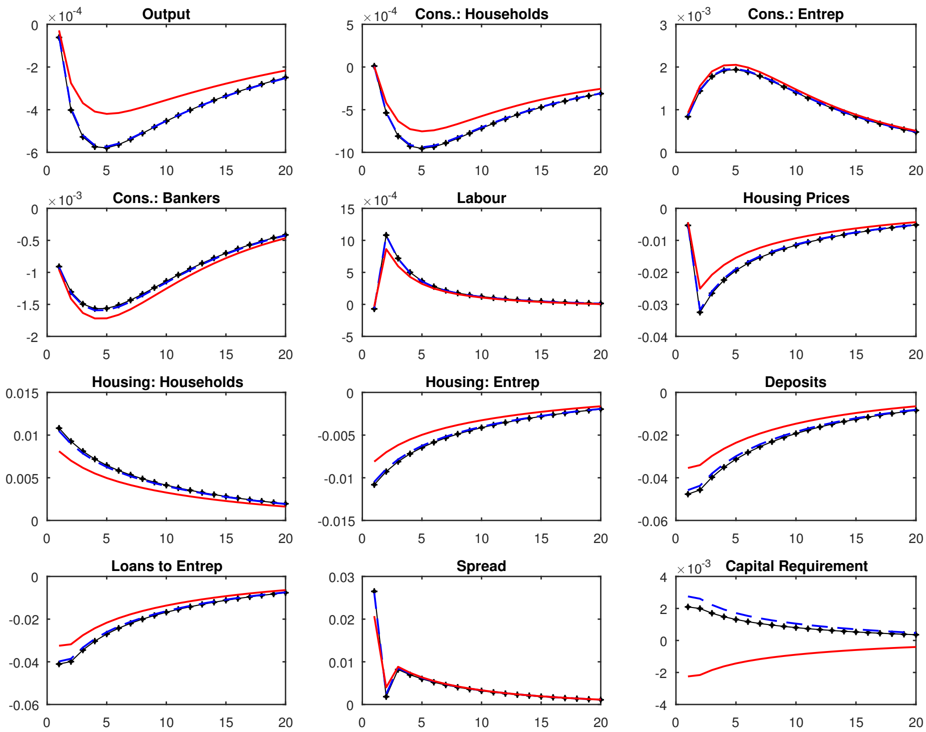

Figure 6: Impulse responses to a negative loan repayment shock under alternative Basel regimes. Notes: Black asterisk line: Basel II; Blue dashed line: Basel II.5; Red solid line: Basel III. Variables are expressed in % deviations from steady states, and interest rates are in percentage points.

Under the Basel II regime, CAR increases in response to the shock and this forces bankers to reduce credit supply. This amplifies the initial impact of the shock and results in a further decline in bank lending, while the lending rate (interest rate spread) increases. This induces a large decline in housing prices and exacerbates the negative impact of the shock on business cycle fluctuations.

The move towards higher capital requirement (Basel II.5) plays a negligible role in moderating the pro-cyclicality of the Basel II regime on financial and real variables. It is the full implementation of Basel III that has pronounced effect in mitigating the impact of the shock. Under the Basel III regime, the fall in the credit-to-GDP ratio deactivates the counter-cyclical capital buffer, which helps bankers to better absorb the impact of the negative financial shock. This mitigates the decline in credit. Consequently, the extent of the fall in output, housing prices and household consumption becomes smaller.

In general, the results suggest that Basel III is more effective in mitigating the negative effects of the shock and attenuating fluctuations in financial and real variables when the economy is hit by financial shocks. The argument is that Basel III enhances bankers' ability to absorb the impact of a negative shock and curb rapid de-leveraging in the banking sector. This helps in mitigating the problem of credit squeeze in economic downturns and fostering greater financial and economic stability. The impact of Basel III in mitigating fluctuations in output, aggregate consumption and housing prices is also visible. This is contrary to the case of a productivity shock, where Basel III has a significant impact on financial variables. These results are consistent with other studies (e.g., Angeloni and Faia; 2013, Angelini et al.; 2014, Benes and Kumhof; 2015, Karmakar; 2016, Rubio and Carrasco-Gallego; 2016), which show that Basel III bank capital requirements are effective in attenuating the pro-cyclical effect of the Basel II framework, particularly when the economy is hit by financial shocks.

6.3 Housing demand shock

Figure 7 shows the impulse responses of the main variables following a positive housing demand shock. The shock increases housing prices, and through the collateral channel, enables entrepreneurs to borrow more and increase investment in commercial real estate and production. On impact, the demand for labour also increases. Consequently, output and consumption for households and entrepreneurs increase. Households also increase the supply of deposits. These results are consistent with the VAR evidence reported in sub-section 2.2, suggesting that a positive housing price shock has expansionary effects on the economy.

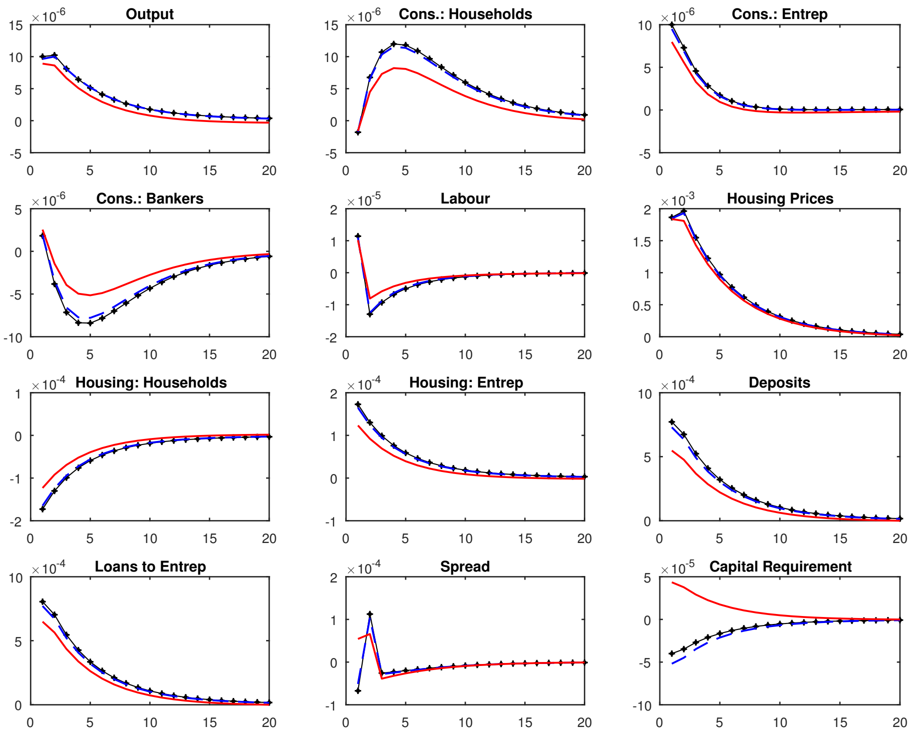

Figure 7: Impulse responses to a positive housing demand shock under alternative Basel regimes. Notes: Black asterisk line: Basel II; Blue dashed line: Basel II.5; Red solid line: Basel III. Variables are expressed in % deviations from steady states, and interest rates are in percentage points.

The results show that the Basel III bank capital regulation regime is effective in attenuating the pro-cyclical effects of its predecessor, in response to the housing demand shock. Under the Basel III regime, the increase in the credit-to-GDP ratio activates the counter-cyclical buffer. This attenuates the increases in housing prices and credit. The increases in output, household and entrepreneur consumption become smaller. Under the Basel II regime, the relaxation of capital requirements amplifies the impact of the shock and induces pro-cyclical financial and business cycles. The introduction of the static component of Basel III (conservative capital buffer) seems to only have a negligible impact in attenuating the pro-cyclical effects of Basel II.

7 Optimal rule for implementing counter-cyclical capital buffers

Having established that the transition to the Basel III regime mitigates the pro-cyclical effects of Basel II and has the potential to promote financial stability, to complete our analysis, in this section we address the question of the implementation of counter-cyclical buffer.[11]

We consider four alternative policy rules for setting counter-cyclical capital buffers and examine their effectiveness in achieving financial stability. As mentioned earlier, we use the volatility of credit (or credit-to-output ratio) and housing prices as the measures of financial stability, based on the assumption that volatile fluctuations in credit and housing prices are often associated with financial instability. Rule A is given by the macroprudential policy rule (26), in line with the BCBS proposal. The first alternative rule (rule B) assumes that the regulatory authority adjusts capital requirement in response to changes in credit as opposed to its ratio to GDP:

$$\kappa_t = \kappa \left(\frac{L_t}{L} \right)^{\chi_l}, \tag{42}$$

where L is the steady-state value of credit and $\chi_l > 0$ measures policy's response to changes in the credit gap. In rule C, the regulatory authority adjusts capital requirement in response to deviations of credit and output from their steady states:

$$\kappa_t = \kappa \left(\frac{L_t}{L} \right)^{\chi_l} \left(\frac{Y_t}{Y} \right)^{\chi_y}, \tag{43}$$

where Y is the steady-state value of output, while $\chi_l > 0$ and $\chi_y > 0$ measure policy's response to changes in credit and output gaps, respectively. In rule D, capital requirement is reacting to deviations of credit, housing prices and output from their steady states:

$$\kappa_t = \kappa \left(\frac{L_t}{L} \right)^{\chi_l} \left(\frac{q_t}{q} \right)^{\chi_q} \left(\frac{Y_t}{Y} \right)^{\chi_y}, \tag{44}$$

where q is the steady-state value of housing prices and the coefficients $\chi_l > 0$, $\chi_q > 0$ and $\chi_y > 0$ measure policy's response to changes in credit, housing prices and output gaps, respectively.

Rule B captures the intuition behind the Basel III counter-cyclical capital buffer: to protect the banking sector from excessive fluctuations in credit which could have negative implications for financial stability. In the case of SA where the regulatory authority is not only concerned about excessive fluctuations in credit but also fluctuations in asset prices such as housing prices, rule D seems to be the suitable

[11] This issue still remains an open question in the literature. See section 1 for a detailed discussion of this.

option. In a way, the three alternative policy rules can be thought of as attempts to address some of the critics of the counter-cyclical rule, especially the use of the credit-to-GDP ratio as a reference guide for taking buffer decisions.

In order to make a concise comparison between the four alternative policy rules, we employ a standard (frequently used) criterion, whereas the main objective of the authority is to minimise volatilities in key policy variables: primarily, the credit-to-GDP ratio, asset prices and output. Along the lines of Angelini et al. (2014), we define the macroprudential authority's loss function as follows:

$$L_{mp} = \sigma_x^2 + \lambda_q \sigma_q^2 + \lambda_\kappa \sigma_\kappa^2 + \lambda_y \sigma_y^2, \tag{45}$$

where σ_x^2, σ_q^2, σ_κ^2 and σ_y^2 are the unconditional variances of credit-to-GDP (or credit in rule B), housing prices, macroprudential instrument (CAR) and output, respectively. The parameters $0 \leq \lambda_q \leq 1$, $0 \leq \lambda_\kappa \leq 1$ and $0 \leq \lambda_y \leq 1$ represent the relative weights on housing prices, the policy instrument and output variabilities in the loss function. Consistent with the broad objective of macroprudential policy, the aim of the authority is to reduce systemic risk by stabilizing fluctuations in credit and to the extent possible excess volatility in asset prices (housing prices) and output. In essence, the loss function (45) implies that the macroprudential authority strives to achieve financial stability (measured by fluctuations in credit and housing prices) without compromising macroeconomic stability (measured by output fluctuations). The inclusion of changes in the policy instrument captures the notion that the authority may want to avoid undue fluctuations in the policy instrument, and needs to hold its movements within reasonable bounds (Angelini et al.; 2014). This exercise will help to establish the optimal parameters (χ_x, χ_l, χ_q, χ_y) that minimise (45) subject to the constraints given by the model.

Table 3: Optimal policy parameters.

Policy rule	Parameter	Weighting scheme $(\lambda_\kappa, \lambda_q, \lambda_y)$			
		$(0.1, 0.0, 0.0)$	$(0.1, 0.0, 5)$	$(0.1, 0.5, 0.0)$	$(0.1, 0.5, 0, 5)$
Policy rule A	χ_x	0.7138	0.7138	0.7138	0.7138
Loss function value		0.0151	0.0151	0.0208	0.0209
Policy rule B	χ_l	0.7164	0.7164	0.7164	0.7164
Loss function value		0.0124	0.0124	0.0179	0.0179
Policy rule C	χ_l	0.7392	0.7394	0.7411	0.7410
	χ_y	6.3252	6.3391	6.8040	6.8057
Loss function value		0.0018	0.0019	0.0058	0.0058
Policy rule D	χ_l	0.7542	1.0206	0.7575	0.7582
	χ_q	3.2280	2.9895	3.4587	3.4574
	χ_y	2.0698	1.9372	2.2482	2.2474
Loss function value		0.0021	0.0019	0.0062	0.0062

Table 3 reports the optimised parameters for each of the four policy rules together with the values of the objective function under the four different weighting schemes. We hold the weight on the policy instrument at constant $\lambda_\kappa = 0.1$ and conduct experiments with different values of the relative weights on output and housing prices within the following ranges: $\chi_i = [0, 0.5] \ \forall \quad i = q, y$. In column three, it is assumed that the authority only cares about fluctuations in credit cycles. In columns four and five, the assumption is that the authority also attaches some weights on the stabilisation of either output (column four) or housing prices (column five). In the last column it assumes that the authority not only cares about financial stability but also macroeconomic stability. In effect, columns three and five are consistent with the financial stability objective with different degrees of asset prices stabilization, while the fourth column and the last column take into account both financial and macroeconomic stability.

The results suggest that moving from rule A to rule B (the authority adjusts bank capital requirement in response to changes in credit only) reduces welfare loss. When the authority follows rule C and adjusts the policy instrument to changes in credit and output, the loss function value decreases tremendously. To optimise rule C, the authority needs to aggressively respond to changes in output (as indicated by a big value of χ_y compared to χ_x and χ_l). Moving from rule C to rule D results in a slight increase in welfare loss. This implies that the inclusion of housing prices in the macroprudential policy reaction function (rule D) does not necessarily enhance the effectiveness of the policy. However, under rule D the authority does not need to respond to changes in output as aggressively as under rule C: χ_y decreases significantly under rule D. In comparison with rules A and B, in which the authority reacts solely to a measure of credit (either credit or credit-to-GDP), the results indicate that rules C and D are optimal for the implementation of the counter-cyclical buffer.

In the nutshell, the results show that the inclusion of output (and housing prices) in the policy rule enhances the effectiveness of macroprudential policy in stabilizing volatilities of financial and real variables. Nevertheless, the most effective policy rule is the one in which the authority adjusts capital requirement to changes in credit and output (rule C). Including housing prices in the policy rule (rule D) significantly reduces the extent that the authority needs to respond to changes in output. These results hold irrespective of whether the objective of the authority is financial stability only (columns three and five) or both financial and macroeconomic stability (columns four and six). Lastly, the optimized policy coefficients remain virtually unchanged, regardless the weighting schemes.

8 Conclusion

The paper presents a real business cycle DSGE model with a stylised banking sector and macroprudential authority, and studies the effectiveness of the Basel III counter-cyclical capital buffer and the transmission mechanisms through which it attenuates the pro-cyclicality of Basel II in the context of South African economy. We decompose the transition from Basel II to Basel III into two stages, namely the increase of CAR by 2.5 percent in line with the conservation buffer and the additional counter-cyclical buffer. We find that it is the counter-cyclical capital buffer that effectively mitigates the pro-cyclicality of its predecessor, while the impact of the conservative buffer is marginal. Basel III has a pronounced impact on financial sector compared to the real sector and is more effective in mitigating fluctuations in financial and business cycles when the economy is hit by financial shocks. The comparison analysis suggests that the optimal rule for implementing the Basel III counter-cyclical buffer is the one in which the authority adjusts capital requirement to changes in credit and output, as opposed to credit-to-GDP proposed by the BIS.

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A Complete set of equations for the baseline model

Households

$$C_{s,t} + D_t + q_t(H_{s,t} - H_{s,t-1}) = W_t N_t + R_{d,t-1} D_{t-1}, \tag{A.1}$$

$$1 = \beta_s E_t \frac{U_{Cs,t+1}}{U_{Cs,t}} R_{d,t}, \tag{A.2}$$

$$q_t = j \frac{A_t}{H_{s,t} U_{Cs,t}} + \beta_s E_t \left(\frac{U_{Cs,t+1}}{U_{Cs,t}} \right) q_{t+1}, \tag{A.3}$$

$$W_t = \frac{\tau}{(1 - N_t) U_{Cs,t}}, \tag{A.4}$$

where $U_{Cs,t} = (1 - \eta_s)/(C_{s,t} - \eta_s C_{s,t-1})$.

Entrepreneurs

$$C_{e,t} + q_t(H_{e,t} - H_{e,t-1}) + R_{e,t} L_{e,t-1} + W_t N_t + AC_{le,t} = Y_t + L_{e,t} + \zeta_t, \tag{A.5}$$

$$Y_t = Z_t H_{e,t-1}^{\nu} N_t^{1-\nu}, \tag{A.6}$$

$$L_{e,t} = m_e E_t \left(\frac{q_{t+1}}{R_{e,t+1}} H_{e,t} \right), \tag{A.7}$$

$$q_t = \beta_e E_t \frac{U_{Ce,t+1}}{U_{Ce,t}} \left(\nu \frac{Y_{t+1}}{H_{e,t}} + (1 - m_e) q_{t+1} \right) + m_e E_t \frac{q_{t+1}}{R_{e,t+1}} - m_e AC'_{le,t} E_t \frac{q_{t+1}}{R_{e,t+1}}, \tag{A.8}$$

$$(1 - \nu) Y_t = W_t N_t, \tag{A.9}$$

where $AC_{le,t} = (\phi_{le}/2L_e)(L_{e,t} - L_{e,t-1})^2$, $AC'_{le,t} = (\phi_{le}/L_e)(L_{e,t} - L_{e,t-1})$ and $U_{Ce,t} = (1 - \eta_e)/(C_{e,t} - \eta_e C_{e,t-1})$

Bankers

$$C_{f,t} + R_{d,t-1} D_{t-1} + L_{e,t} + AC_{lf,t} = D_t + R_{e,t} L_{e,t-1} - \zeta_t, \tag{A.10}$$

$$D_t = (1 - \kappa_t)[L_{e,t} - \zeta_{t+1}], \tag{A.11}$$

$$1 - (1 - \kappa_t) + AC'_{ef,t} = \beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} (R_{e,t+1} - (1 - \kappa_t) R_{d,t}), \tag{A.12}$$

where $AC_{ef,t} = (\phi_{ef}/2L_e)(L_{e,t} - L_{e,t-1})^2$, $AC'_{ef,t} = (\phi_{ef}/L_e)(L_{e,t} - L_{e,t-1})$ and $U_{Cf,t} = (1 - \eta_f)/(C_{f,t} - \eta_f C_{f,t-1})$.

Housing market:

$$H_{s,t} + H_{e,t} = 1. \tag{A.13}$$

Macroprudential policy rule:

$$\kappa_t = \kappa \left(\frac{L_{e,t}/Y_t}{L/Y} \right)^{\chi_x}. \tag{A.14}$$

Interest rate spread:

$$Sprd_t = R_{e,t+1} - R_{d,t}. \tag{A.15}$$

Aggregate consumption:

$$C_t = C_{s,t} + C_{e,t} + C_{f,t}. \tag{A.16}$$

Shocks:

$$log(A_t) = \rho_a log(A_{t-1}) + \xi_{a,t}, \tag{A.17}$$

$$\zeta_t = \rho_\zeta \zeta_{t-1} + \xi_{\zeta,t}, \tag{A.18}$$

$$log(Z_t) = \rho_z log(Z_{t-1}) + \xi_{z,t}. \tag{A.19}$$

The model has 16 endogenous variables; $C_{s,t}$, $C_{e,t}$, $C_{f,t}$, C_t, $H_{s,t}$, $H_{e,t}$, N_t, W_t, q_t, D_t, $L_{e,t}$, $R_{d,t}$, $R_{e,t}$, $Sprd_t$, Y_t and κ_t. There are 3 exogenous shocks; A_t, ζ_t and Z_t.

B Steady-state of the baseline model

$$R_d = 1/\beta_s, \tag{B.1}$$

$$R_e = 1/\beta_f - (1-\kappa)(1/\beta_f - 1/\beta_s), \tag{B.2}$$

$$\Omega_1 = 1 - \beta_e - m_e(1/R_e - \beta_e), \tag{B.3}$$

$$\Omega_2 = 1 - \nu, \tag{B.4}$$

$$\Omega_3 = 1 + (R_d - 1)(1-\kappa)[\nu\beta_e m_e / R_e \Omega_1 \Omega_2], \tag{B.5}$$

$$\frac{H_e}{(H_e + H_s = 1)} = \frac{\nu\beta_e(1-\beta_s)}{\nu\beta_e(1-\beta_s) + j\Omega_1\Omega_2\Omega_3}, \tag{B.6}$$

$$q = \frac{\nu\beta_e}{\Omega_1}\frac{Y}{H_e}, \tag{B.7}$$

$$L_e = m_e \nu \beta_e \frac{1}{R_e \Omega_1} Y, \tag{B.8}$$

$$D = (1-\kappa)L_e, \tag{B.9}$$

$$C_f = (1 - R_d)D + (R_e - 1)L_e, \tag{B.10}$$

$$N = 1/(1 + \tau\Omega_3), \tag{B.11}$$

$$W = \Omega_2 Y/N, \tag{B.12}$$

$$Cs = WN + (R_d - 1)D, \tag{B.13}$$

$$C_e = Y + (1 - R_e)L_e - WN, \tag{B.14}$$

$$Sprd = R_e - R_d, \tag{B.15}$$

$$H_s + H_e = 1. \tag{B.16}$$

C Complete set of equations for the extended model

C.1 Patient households (savers)

Patient households maximize their expected lifetime utility function:

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

subject to the budget constraint:

$$C_{s,t} + D_t + q_t(H_{s,t} - H_{s,t-1}) = W_{s,t} N_{s,t} + R_{d,t-1} D_{t-1}. \tag{C.2}$$

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

$$1 = \beta_s E_t \frac{U_{Cs,t+1}}{U_{Cs,t}} R_{d,t}, \tag{C.3}$$

$$q_t = j \frac{A_t}{H_{s,t} U_{Cs,t}} + \beta_s E_t \left(\frac{U_{Cs,t+1}}{U_{Cs,t}} \right) q_{t+1}, \tag{C.4}$$

$$W_{s,t} = \frac{\tau}{(1 - N_{s,t}) U_{Cs,t}}. \tag{C.5}$$

C.2 Impatient households (borrowers)

Impatient households maximize their expected lifetime utility function:

$$E_0 \sum_{t=0}^{\infty} \beta_b^t \Big[(1-\eta_b) log(C_{b,t} - \eta_b C_{b,t-1}) + jA_t log(H_{b,t}) + \tau log(1 - N_{b,t})\Big], \tag{C.6}$$

subject to the budget constraint:

$$C_{b,t} + R_{b,t-1} L_{b,t-1} + q_t(H_{b,t} - H_{b,t-1}) + AC_{lb,t} = W_{b,t} N_{b,t} + L_{b,t} + \zeta_{b,t}, \tag{C.7}$$

and the borrowing constraint:

$$L_{b,t} \le m_b E_t \left[\frac{q_{t+1}}{R_{b,t}} H_{b,t} \right]. \tag{C.8}$$

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

$$1 = \beta_b E_t \frac{U_{Cb,t+1}}{U_{Cb,t}} R_{b,t} + \frac{\lambda_{b,t}}{U_{Cb,t}} + \frac{\phi_{lb}}{L_b}(L_{b,t} - L_{b,t-1}), \tag{C.9}$$

$$q_t = j \frac{A_t}{H_{b,t} U_{Cb,t}} + \beta_b E_t \left(\frac{U_{Cb,t+1}}{U_{Cb,t}} \right) q_{t+1} + m_b (\lambda_{b,t}/U_{Cb,t}) E_t \frac{q_{t+1}}{R_{b,t}} t, \tag{C.10}$$

$$W_{b,t} = \frac{\tau}{(1 - N_{b,t}) U_{Cb,t}}. \tag{C.11}$$

C.3 Entrepreneurs

Entrepreneurs maximize their expected lifetime utility function:

$$E_0 \sum_{t=0}^{\infty} \beta_e^t (1-\eta_e) log(C_{e,t} - \eta_e C_{e,t-1}), \tag{C.12}$$

subject to the budget constraint:

$$C_{e,t} + q_t(H_{e,t} - H_{e,t-1}) + R_{e,t}L_{e,t-1} + W_{s,t}N_{s,t} + W_{b,t}N_{b,t} + AC_{le,t} = Y_t + L_{e,t} + \zeta_{e,t}, \tag{C.13}$$

and the borrowing constraint:

$$L_{e,t} \leq m_e E_t \left[\frac{q_{t+1}}{R_{e,t+1}} H_{e,t} \right]. \tag{C.14}$$

Production technology is given by a constant-return to scale Cobb-Douglas production function:

$$Y_t = Z_t H_{e,t-1}^{\nu} [N_{s,t}^{1-\sigma} N_{b,t}^{\sigma}]^{1-\nu}. \tag{C.15}$$

Let $U_{Ce,t} = \frac{1-\eta_e}{C_{e,t} - \eta_e C_{e,t-1}}$ denote the marginal utility of consumption and $\lambda_{e,t}$ denote the multiplier on the borrowing constraint (C.14), the first order conditions which define entrepreneurs' problem are as follows:

$$q_t = \beta_e E_t \frac{U_{Ce,t+1}}{U_{Ce,t}} \left(\nu \frac{Y_{t+1}}{H_{e,t}} + q_{t+1} \right) + m_e(\lambda_{e,t}/U_{Ce,t}) E_t \frac{q_{t+1}}{R_{e,t+1}}, \tag{C.16}$$

$$W_{s,t}N_{s,t} = (1-\sigma)(1-\nu)Y_t, \tag{C.17}$$

$$W_{b,t}N_{b,t} = \sigma(1-\nu)Y_t, \tag{C.18}$$

$$1 - \frac{\phi_{le}}{L_e}(L_{e,t} - L_{e,t-1}) = \lambda_{e,t}/U_{Ce,t} + \beta_e E_t \frac{U_{Ce,t+1}}{U_{Ce,t}} R_{e,t+1}. \tag{C.19}$$

C.4 Financial intermediaries

Financial intermediaries maximize their expected lifetime utility function:

$$E_0 \sum_{t=0}^{\infty} \beta_f^t (1-\eta_f) log(C_{f,t} - \eta_f C_{f,t-1}), \tag{C.20}$$

subject to the budget constraint:

$$C_{f,t} + R_{d,t-1}D_{t-1} + L_{b,t} + L_{e,t} + AC_{bf,t} + AC_{ef,t} = D_t + R_{b,t-1}L_{b,t-1} + R_{e,t}L_{e,t-1} - \zeta_{b,t} - \zeta_{e,t}, \tag{C.21}$$

and the capital requirement constraint:

$$D_t \leq (1 - w_e\kappa_t)[L_{e,t} - E_t\zeta_{e,t+1}] + (1 - w_b\kappa_t)[L_{b,t} - E_t\zeta_{b,t+1}]. \tag{C.22}$$

Let $U_{Cf,t} = \frac{1-\eta_f}{C_{f,t} - \eta_f C_{f,t-1}}$ denote the marginal utility of consumption and $\lambda_{f,t}$ denote the multiplier on the capital adequacy constraint, the bank's optimal condition for deposits and credit are given by:

$$1 - \lambda_{f,t}/U_{Cf,t} = \beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} R_{d,t}, \tag{C.23}$$

$$\beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} R_{e,t+1} = 1 - (\lambda_{f,t}/U_{Cf,t})(1 - w_e \kappa_t) + \frac{\phi_{ef}}{L_e}(L_{e,t} - L_{e,t-1}), \tag{C.24}$$

$$\beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} R_{b,t} = 1 - (\lambda_{f,t}/U_{Cf,t})(1 - w_b \kappa_t) + \frac{\phi_{bf}}{L_b}(L_{b,t} - L_{b,t-1}). \tag{C.25}$$

Combining (C.23) - (C.25), we can derive the interest rate differentials between the bank loan rate and the risk-free rate:

$$R_{e,t+1} - R_{d,t} = \frac{1}{\beta_f} E_t \frac{U_{Cf,t}}{U_{Cf,t+1}} \left[w_e \kappa_t (\lambda_{f,t}/U_{Cf,t}) + \frac{\phi_{ef}}{L_e}(L_{e,t} - L_{e,t-1}) \right], \tag{C.26}$$

$$R_{b,t} - R_{d,t} = \frac{1}{\beta_f} E_t \frac{U_{Cf,t}}{U_{Cf,t+1}} \left[w_b \kappa_t (\lambda_{f,t}/U_{Cf,t}) + \frac{\phi_{bf}}{L_b}(L_{b,t} - L_{b,t-1}) \right]. \tag{C.27}$$

In the steady state, equations (C.4) and (C.23) imply that

$$\lambda_f C_f = \frac{\beta_s - \beta_f}{\beta_s} > 0. \tag{C.28}$$

That is, as long as bankers are impatient than savers ($\beta_f < \beta_s$), bankers' capital adequacy constraint holds with equality.

This further implies that, in the steady state,

$$R_e - R_d = \frac{1}{\beta_f}(\lambda_f C_f) w_e \kappa > 0, \tag{C.29}$$

$$R_b - R_d = \frac{1}{\beta_f}(\lambda_f C_f) w_b \kappa > 0, \tag{C.30}$$

with $0 < \kappa < 1$. The necessary condition for entrepreneurs' borrowing constraint to hold with equality is

$$\frac{1}{\beta_e} > R_e. \tag{C.31}$$

Alternatively, the condition for entrepreneur's borrowing constraint to hold with equality requires

$$\beta_e < \frac{1}{w_e \kappa \frac{1}{\beta_f} + (1 - w_e \kappa) \frac{1}{\beta_s}}. \tag{C.32}$$

Similarly, for impatient households' borrowing constraint to hold with equality in the steady state, it require

$$\frac{1}{\beta_b} > R_b, \tag{C.33}$$

or,

$$\beta_b < \frac{1}{w_b \kappa \frac{1}{\beta_f} + (1 - w_b \kappa) \frac{1}{\beta_s}}. \tag{C.34}$$

C.5 Shocks

$$log(A_t) = \rho_a log(A_{t-1}) + \xi_{a,t}, \tag{C.35}$$

$$\zeta_{b,t} = \rho_\zeta \zeta_{b,t-1} + \xi_{\zeta_b,t}, \tag{C.36}$$

$$\zeta_{e,t} = \rho_\zeta \zeta_{e,t-1} + \xi_{\zeta_e,t}, \tag{C.37}$$

$$log(Z_t) = \rho_z log(Z_{t-1}) + \xi_{z,t}. \tag{C.38}$$

D Pro-cyclical effects of Basel regimes: The extended model

To get more insight on how the transition from Basel II to Basel III affects different agents in the economy, this section presents simulation results with the extended model under the two Basel regimes following the same shocks. For the sake of brevity, we discuss the results for the variables that have been affected by the modifications in the extended model in more detail and only briefly summarise the rest. The discussion focuses on a complete transition to the Basel III regulation.[12]

D.1 Technology shock

Figure 8 presents the impulse responses of the main variables to a positive technology shock under the two Basel regimes. The shock increases household borrowers' and entrepreneurs' demand for housing and, hence, housing prices. Through the borrowing constraint channel, this enables both types of borrowers to demand more credit. Consequently, consumption for all agents and output increase.

Under the Basel II regime, bank capital requirement decreases in an economic boom and this allows bankers to provide more credit to household borrowers and entrepreneurs. This generates more profits for bankers and increases their consumption. This generates a large increase in both types of borrowers' demand for housing and consumption. However, under Basel III, the regulatory authority activates the counter-cyclical buffer when the economy enters into a boom. To meet higher CAR, bankers restrain lending to both household borrowers and entrepreneurs. This attenuates the increase in household borrowers' and entrepreneurs' demand for housing and consumption.

The results further show that the impact of Basel III is unevenly distributed across agents. The new regime attenuates the impact of the productivity shock on households' and entrepreneurs' consumption, but amplifies that of bankers. Hence, the aggregated impact of the Basel III regulation on output is marginal.

D.2 Loan repayment shock (household borrower)

Figure 9 shows the impulse responses of the main variables following a negative loan repayment shock (household borrower).[13] The shock reduces bankers' net worth and, through the bank capital constraint channel, leads to a fall in credit supply to both household borrowers and entrepreneurs. As a consequence,

[12] We exclude the Basel II.5 regime in this section.

[13] In this section, we only report the results for the household borrower loan repayment shock. The results for the entrepreneur loan repayment shock are similar to those of the household borrower loan repayment shock. The only difference is that, in the case of the entrepreneur loan repayment shock, entrepreneurs' consumption increases while that of household borrowers does not. Furthermore, additional resources (due to income redistribution from bankers to entrepreneurs) enable entrepreneurs to hire more labour and boost production over time.

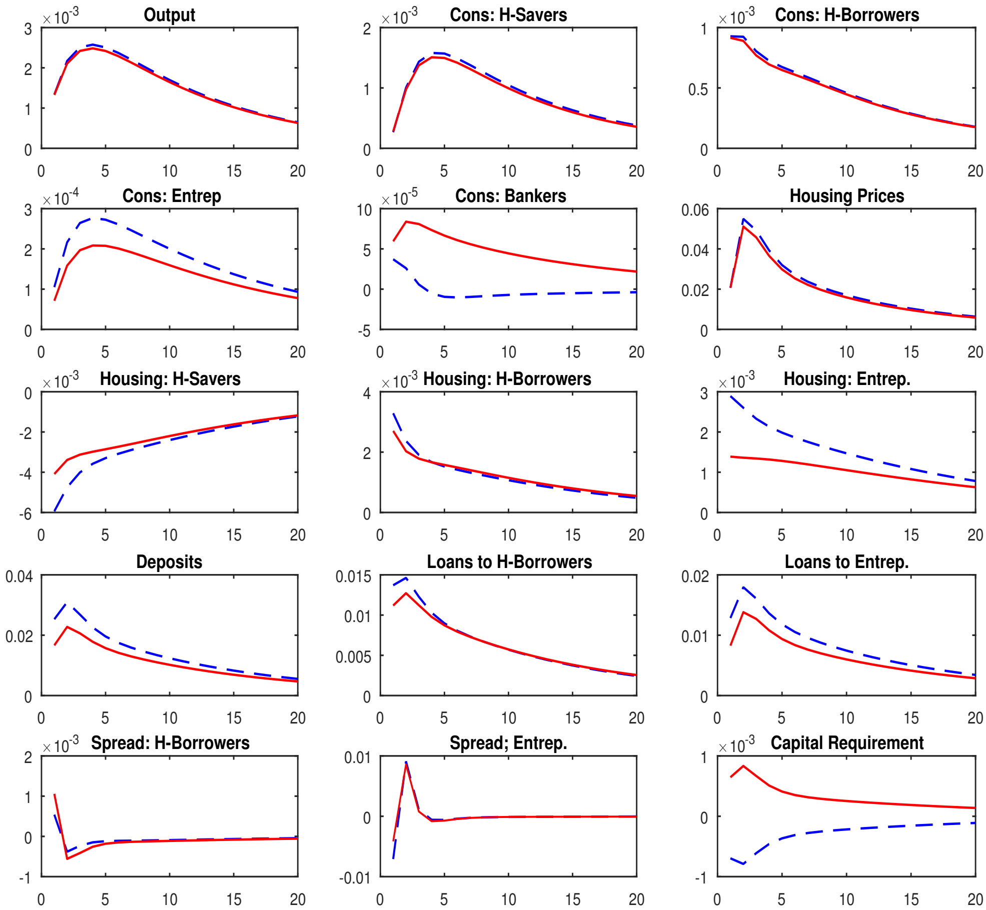

Figure 8: Impulse responses to a positive productivity shock under alternative Basel regimes. Notes: Blue dashed line: Basel II; Red solid line: Basel III. Variables are expressed in % deviations from steady states, and interest rates are in percentage points.

the demand of household borrowers and entrepreneurs for housing and housing prices declines. The shock also results in a protracted decline in output and agents' consumption except for household borrowers. For household borrowers, the shock increases their income: by paying less than the contractual amount of loans, borrowers are able to spend more than previously anticipated.

Under the Basel II regime, CAR increases and this forces bankers to take necessary measures to meet the higher capital requirement. As a result, bankers curtail both the demand for deposits and credit supply to both household borrowers and entrepreneurs. This exacerbates the recessionary effects of the shock and induces a large fall in household borrowers' and entrepreneurs' demand for housing, consumption and output. In contrast, under the Basel III regime, regulatory requirement becomes accommodative in recession and bank capital requirements temporarily fall. This assists bankers to better absorb the impact of the shock without being forced to rapidly de-leverage. Consequently, the extent of the fall in credit supply to both household borrowers and entrepreneurs becomes smaller. This also attenuates the fall in household borrowers' and entrepreneurs' demand for housing and output.

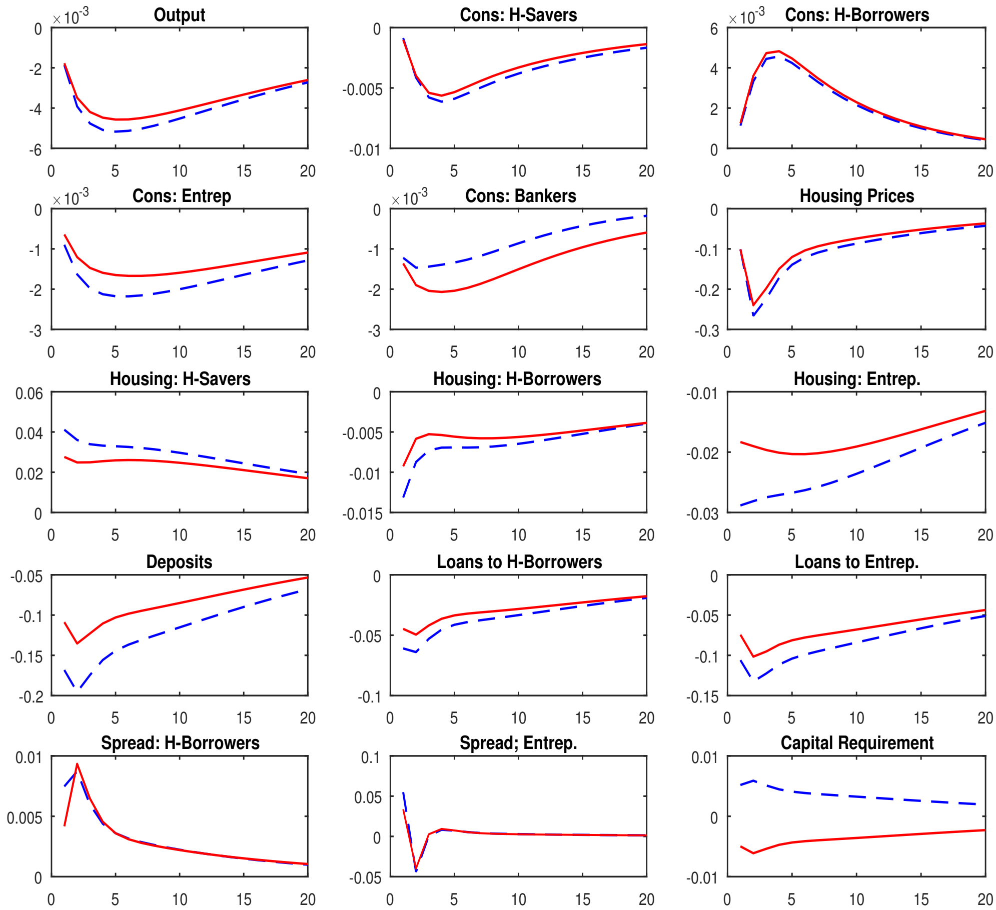

Figure 9: Impulse responses to a negative loan repayment shock (household borrower) under two Basel regimes. Notes: Blue dashed line: Basel II; Red solid line: Basel III. Variables are expressed in % deviations from steady states, and interest rates are in percentage points.

Bankers further curtail consumption and make additional resources available for lending, which can mitigate the fall in credit supply.

D.3 Housing demand shock

Figure 10 depicts the impulse responses of the main variables to a positive housing demand shock. Under Basel II, the shock increases housing prices and, through the borrowing constraint channel, results in an increase in household borrowers' and entrepreneurs' demand for credit. This stimulates output growth and consumption for household savers and entrepreneurs. For household borrowers, the increased preference for housing services creates incentives for them to substitute from consumption to housing. As such, household borrowers' consumption declines. To accommodate higher lending, bankers reduce consumption.

Under Basel III, CAR increases in response to the increase in the credit-to-GDP ratio. In an attempt

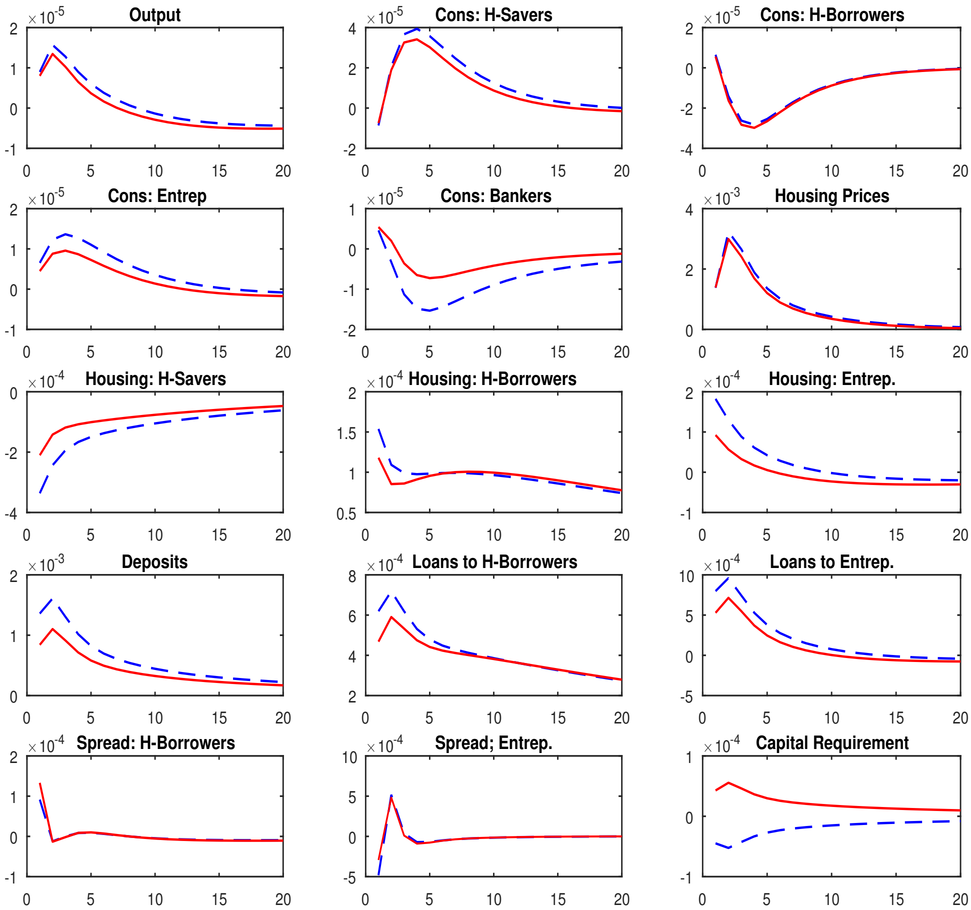

Figure 10: Impulse responses to a positive housing demand shock under two Basel regimes. Notes: Blue dashed line: Basel II; Red solid line: Basel III. Variables are expressed in % deviations from steady states, interest rates are in percentage points.

to meet higher CAR, bankers refrain from providing more credit to entrepreneurs and household borrowers. This attenuates the extent of the increase in entrepreneurs' and household borrowers' demand for housing, housing prices and output. This is in contrast to the case under the Basel II regime. Under Basel II, the decrease of capital requirement promotes more lending and amplifies the impact of the shock on fluctuations in both financial and real variables. These results are along the lines of the findings in the literature (see e.g., Repullo and Suarez; 2013, Angeloni and Faia; 2013, Angelini et al.; 2014, 2015, Gersbach and Rochet; 2017), where the authors show that Basel III is effective in mitigating pro-cyclical effects of Basel II and has potential to promote financial stability.