FINANCIAL STABILITY AND MACROPRUDENTIAL OVERSIGHT DEPARTMENT

P O Box 2882, Windhoek, Namibia

Tel: +264-61-283 5111

Fax: +264-61-283 5067

E-mail: Financial.Stability@BON.COM.NA

The implementation of a Countercyclical Loan-To-Value (CcLTV) ratio in Namibia

Sabina Mufika, *Bank of Namibia: e-mail: sabina.mufika@bon.com.na*

Andy Esterhuizen, *Bank of Namibia: e-mail: andy.esterhuizen@bon.com.na*

Sylviano Afrikaner, *Bank of Namibia: e-mail: sylviano.afrikanner@bon.com.na*

Jaungura Kaune, *Bank of Namibia: email: jaungura.kaune@bon.com.na*

In consultation with:

Prof.* Guangling *Liu, *University of Stellenbosch: email: gliu@sun.ac.za*

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P O Box 2882

WINDHOEK

NAMIBIA

Tel: +264 61 283 5111

Fax: +264 61 2835067

E-mail: financial.stability@bon.com.na

http://www.bon.com.na

Abstract

The study evaluated the impact of the constant LTV ratio and the countercyclical loan-to-value (CcLTV) ratio regimes on financial and macroeconomic stability and proposes the adoption of a CcLTV ratio as a macroprudential policy tool in Namibia. This was achieved through a structured dynamic stochastic general equilibrium model with financial frictions, using quarterly data for the period 2000Q1 to 2023Q4. The analysis revealed that while the constant LTV regime generates uniform responses to shocks, the CcLTV regime provides greater flexibility, mitigating the adverse effects of financial shocks and dampening housing market fluctuations. The efficiency policy frontier, which highlights the trade-offs between financial stability and macroeconomic objectives, showed that the CcLTV regime is more effective in containing financial instability under financial shocks. Welfare analysis indicated that savers and banks benefit more from the CcLTV regime, while borrowers and entrepreneurs fare better under the constant regime due to reduced risk exposure. Overall, the study found that while constant LTV ratios provide stability in certain contexts, the CcLTV ratio regime is a more effective tool for addressing sector-specific risks, particularly in periods of financial distress. The key recommendations include the consideration of borrower heterogeneity and tailoring the CcLTV regulation according to the specific conditions of each sector of the credit market, developing the CcLTV ratio framework, and enhancing the existing LTV ratio Determination, as well as benchmarking with international best practice. Timely and adequate calibration, considering the macrofinancial environment, is therefore crucial. For an effective policy framework, it is recommended that both stakeholders and experts from the financial and regulatory sectors be engaged.

Contents

1. Introduction

Many financial crises[1] are linked to housing bubbles driven by over-leveraged households and banks. These crises revealed the limitations of microprudential regulation in addressing systemic risks, as the unwinding of excessive leverage, particularly within the housing market, exposed vulnerabilities. This underscored the importance of macroprudential policies working in conjunction with microprudential measures to ensure a comprehensive approach to financial stability. In response, the Basel III framework introduced by the Bank for International Settlements (BIS) incorporated macroprudential regulation as an overlay to existing microprudential tools. In addition to capital buffer requirements, leverage, and liquidity ratios, Basel III included the countercyclical capital buffer, which raises capital requirements during economic upswings and reduces them during downturns. However, Basel III does not sufficiently address the procyclicality in specific, highly leveraged sectors such as housing, which are particularly prone to systemic risk accumulation.

Policymakers and the International Monetary Fund (IMF) have since explored borrower-based measures, such as loan-to-value (LTV) ratios, debt-service-to-income, and loan-to-income ratios, as macroprudential tools to manage housing market risks by limiting borrowing and enhancing household sector resilience (O'Brien & Ryan, 2016). The implementation of these measures varies across jurisdictions, reflecting diverse approaches to managing housing market imbalances. Borio, Furfine, and Lowe (2001) argue that financial systems often mirror the business cycle, with risk perceptions and asset valuations fluctuating alongside economic conditions. During expansions, increased optimism leads to higher risk-taking and asset bubbles, exacerbating economic overheating. Therefore, LTV ratios can either be deployed cyclically when credit risks emerge, or remain constant as part of the regulatory framework, ensuring prudent lending standards are maintained (O'Brien & Ryan, 2017).

Several jurisdictions, including Hong Kong, China, England, Singapore, Nigeria, Turkey and Sweden have employed constant LTV ratios to contain credit growth in housing markets (Lim et al., 2011).[2] While these constant LTV ratios may prevent some procyclicality during boom periods, they are not strictly countercyclical, as they are not adjusted to the varying risk levels throughout the business cycles. Theoretical work by Stein (1995) also shows that if constant LTV ratios are not relaxed in a timely manner, they may amplify financial instability and the fluctuations of the business cycle. To address this, countercyclical measures aimed at

[1] The Global Financial Crisis of 2007-2008, and the Asian Crisis of 1997-1998 amongst others.

[2] See Table 1 in Appendix A.

reducing systemic risk caused by excessive credit growth and financial sector procyclicality are under consideration (Claessens et al., 2013). One such measure is the countercyclical LTV (CcLTV) ratio, which tightens LTV ratios during economic upswings to temper excessive credit growth and prevent asset bubbles. Conversely, during downturns or periods of low credit demand, the LTV ratio is relaxed to support lending and economic activity. These adjustments make the LTV ratio a more effective countercyclical tool and can be used to “lean against the wind" of potential risks (Robinson & Yao, 2016). CcLTV ratios have been implemented in jurisdictions like Ireland, and New Zealand to enhance financial stability. In Namibia, while there is a constant LTV ratio in place, the use of a countercyclical LTV has not yet been explored.

To bridge this regulatory gap, this study evaluates the impact of the current constant LTV ratio on financial stability and proposes the adoption of a CcLTV ratio as a macroprudential policy tool in Namibia. By proposing the implementation of a CcLTV regulation that responds to changing economic conditions, this study contributes to the Bank of Namibia’s (the Bank) mandate to ensure financial system stability. To achieve this, the study develops a structured dynamic stochastic general equilibrium (DSGE) model with financial frictions. DSGE models have gained prominence for capturing the dynamic nature of economic fluctuations and various agent interactions, leading central banks to incorporate them into their operations for coherent policy analysis frameworks (Kremer et al. 2006; Tovar 2009; Ahmed et al., 2013).

The model developed in this study consists of patient households (savers), impatient households (borrowers), entrepreneurs (corporates) banks, and a macroprudential authority. Borrowers face constraints limiting their borrowing to a certain fraction of their collateral assets’ value. The macroprudential authority adjusts the LTV ratio in a countercyclical manner to promote both financial and macroeconomic stability. To investigate the impact of the two policy regimes (constant LTV and CcLTV ratios), and the transmission mechanisms through which the objective of macroprudential policy is achieved, the study conducts impulse response functions (IRFs) following technology, financial, and housing demand shocks. The study further conducts an efficiency policy frontier (EPF) to assess the trade-off between macroeconomic stability and financial stability. This study uses the volatility of credit as a measure of financial stability and the volatility of output as a measure macroeconomic stability, in line with Agenor and Pereira da Silva (2017) and Liu and Molise (2019). Lastly, the study conducts a welfare analysis to assess the optimal benefits and trade-offs of the two policy interventions.

The study's findings are summarised as follows. The impulse response function analysis reveals that a positive technology shock affects the economy more uniformly under the constant LTV regime, while the CcLTV regime allows for flexibility, resulting in varied outcomes across different economic sectors. In contrast, when faced with a financial shock, the CcLTV regime proves more effective than the constant LTV regime in mitigating the adverse impacts of loan loss shocks on most variables. Similarly, in response to a positive housing demand shock, the CcLTV regime effectively dampens the expansionary impact, resulting in lower fluctuations in both house prices and aggregate loans compared to the constant LTV regime.

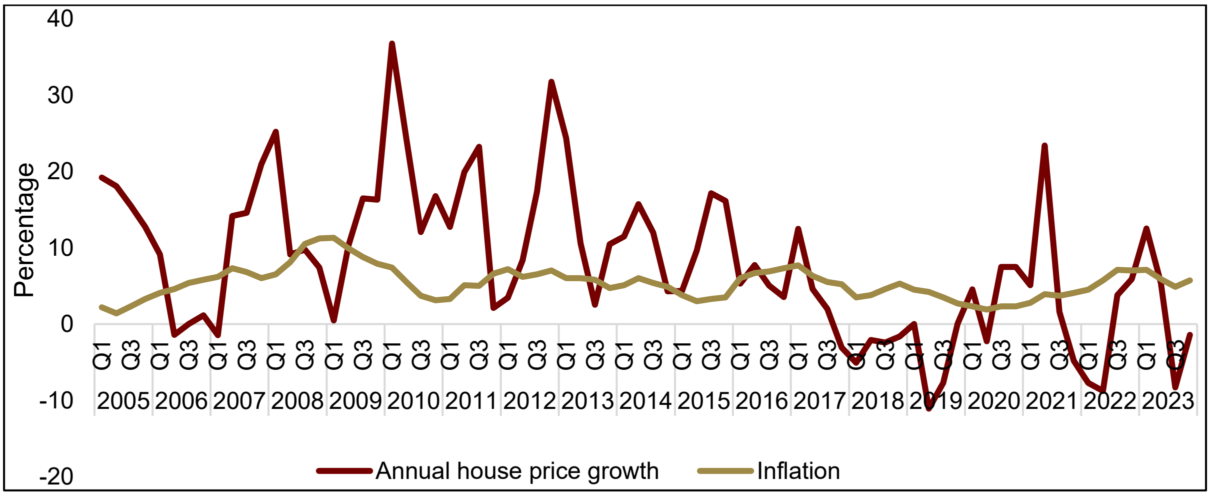
The results from the EPFs indicate that policymakers need to carefully consider the balance between financial and macroeconomic stability, as efforts to stabilise one policy objective may have adverse effects on another. Under the financial shock, the CcLTV regime effectively reduces household loan volatility compared to the constant regime. However, this reduction comes at the cost of increased macroeconomic instability, highlighting a trade-off between financial and macroeconomic stability. Similarly, the results for the EPF under the technology shock indicate that the CcLTV regime also allows for better overall outcomes than the constant case. The CcLTV regime results under the two shocks suggest that the technology shock demonstrates a more balanced trade-off between the two policy objectives. In terms of the implementation of the two regimes, the study finds that the proposed CcLTV regime have the potential to deliver on financial and macroeconomic stability mandates. The welfare analysis indicates that patient households and banks benefit from the CcLTV regime, while impatient households and entrepreneurs find the constant regime more favourable due to its stabilising effects on welfare and reduced financial risk exposure. The financial shock yields the most welfare gains for banks and entrepreneurs, while both patient and impatient households face welfare losses. The technology and housing demand shocks generally show similar welfare patterns across agents.

The rest of the paper is organised as follows: Section 2 discusses the implementation of the LTV regulation in Namibia, followed by the literature review in Section 3. The model is introduced in Section 4, while Section 5 covers the calibration of the model. Section 6 examines the model's business cycle properties, presents the impulse response functions, and discusses the optimal LTV rules. Additionally, the section addresses the EPF and welfare analysis. Section 7 concludes.

2. Implementation of the LTV regulation in Namibia

In 2016, the Bank proposed the introduction of a constant LTV regulation which placed restrictions on the proportion of mortgage lending by domestic financial institutions. This was in response to the rapid growth in house prices and to contain the risk of credit concentration of the commercial banks' loan books to mortgage loans. The LTV regulation primarily targeted non-primary mortgages,[3] aiming to curb speculative behaviour and growth in house prices from outpacing inflation (Figure 1). In addition, the regulation aimed to protect the financial soundness of banks, given their significant exposure to mortgage loans which was at 54.1 percent and 64.3 percent in 2015 and 2016, respectively. Prior to the implementation of the constant LTV ratio, annual house prices averaged 11.2 percent in 2015. This was mainly due to favourable interest rates, and positive economic performance observed at the time which boosted housing demand and subsequently the uptick in house prices. While the introduction of a constant LTV ratio aimed to curb excessive credit growth, it did not account these changing market conditions. A CcLTV ratio, if implemented during this period, could have provided a more adaptive response to emerging imbalances in the housing market. Following the introduction of the LTV regulation in March 2017, the overheated property market cooled down as the house price growth contracted by 3.1 percent at the end of 2017, from a growth of 12.5 percent observed during the first quarter of 2017 (Figure 1). In addition to the introduction of the LTV regulation, the significant decline in house prices is due to the poor economic performance at the time, which was consistent with fiscal consolidation measures, amongst other macroeconomic fundamentals.

Figure 1: House price growth and inflation



Source: Bank of Namibia (BoN)

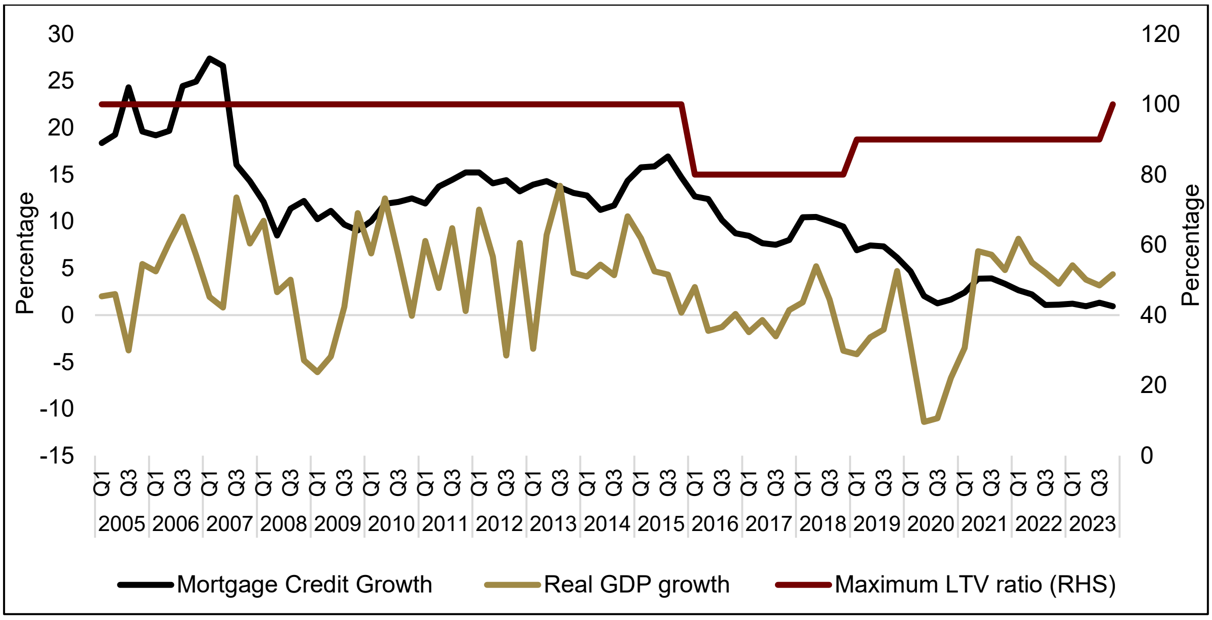
[3] The LTV regulation required buyers of non-primary residential properties to provide a 20 percent deposit when acquiring a home loan, with additional properties requiring higher deposits (Table 4 in Appendix 1).

Vulnerabilities were further noted in the housing market, coupled with elevated interest rates and subdued economic growth. The contraction in house price growth since 2017 persisted, reaching a significant decline of 11.1 percent in the second quarter of 2019 (Figure 1). This called for the revision of the LTV regulation in 2019 (Table 6 in Appendix A) to correct the sharp decline in the demand for credit, house prices, and rapid deleverage in the banking sector. Notwithstanding the eased LTV ratios, the housing market continued to perform poorly, coupled with subdued economic growth (Figure 2). These developments underscore the use of a CcLTV ratio to stimulate investment in the property market, and economic activity. This is aligned with the Guidance note to reconsider LTV ratios for Namibia which suggests that Namibia's LTV ratios are too restrictive (Bank of Namibia, 2023).

Following a period of stagnation in 2022, house prices witnessed a notable improvement in 2023 despite elevated interest rates and subdued economic activity. Concurrently, overall growth in total mortgage credit improved during 2023 compared to 2022. This growth in total mortgage credit, albeit at a slower pace, aligns with the increase in house prices, reflecting the heightened uptake of mortgage credit by the household sector (Figure 3 in Appendix A). Despite the positive momentum, the uptake of mortgage credit remains subdued. Thus, in response to challenges facing the property market, the Bank intervened in October 2023 by implementing less strict LTV ratios to stimulate demand (Table 7 in Appendix A). While the LTV regulation promotes responsible lending and financial stability, it is important for the Bank to be cognisant of the existent credit risk management guidelines[4] and exercise caution with the LTV regulation, considering the bank's exposure to mortgage credit.

Figure 2: Mortgage credit growth and LTV ratio

[4] Guidelines from the Basel Committee, and the Bank which focus on managing credit and concentration risk. The guidelines are enshrined in regulations such as the Determination on Asset Classification, Provisioning and Interest Suspense (BID-2), Determination on Large Exposures and Concentration Risk (BID-4), and Determination on the Measurement and Calculation of Credit, Market and Operational Risk (BID-5A).



Source: BoN

Trends in mortgage lending and house prices are affected by various factors besides the LTV ratio. This makes it difficult to ascertain whether LTV ratios effectively counteract the business cycle, thus hindering the ability to establish a clear relationship between the LTV ratio and house prices. This is consistent with empirical findings by Jia (2019). At the same time, however, literature also indicates that there seems to be a positive correlation between LTV ratios and house price volatility and mortgage credit (Zidonyte, 2015; Robinson and Yao, 2016). This positive correlation is evident in Figure 2, where prior to the introduction of the LTV regulation, total mortgage credit contracted to 8.4 percent during the first quarter of 2017 from a growth of 12.7 percent observed during the first quarter of 2016.[5] The housing market activity was further impacted by a slowdown in real GDP growth due to downturns in the mining, construction, wholesale and retail trade, as well as manufacturing sectors among other factors. The contraction was primarily attributed to fiscal consolidation, coupled with inflationary pressures and higher interest rates from 2016 to 2017. This suggests that the weak economic performance played a significant role in the strain observed in mortgage credit extension and house prices.

[5] See Figure 3 in Appendix A.

3. Literature Review

The countercyclical financial sector regulation aimed at ensuring financial system stability is underpinned by both theoretical and empirical literature. The CcLTV ratio policies are supported by empirical evidence and guidance from regulatory bodies such as the BIS and IMF. These regulatory bodies emphasise the importance of macroprudential regulation in mitigating systemic risks within the financial system. The CcLTV regulation aims to attenuate the credit cycle by imposing lower LTV ratios during periods of excessive credit growth and higher ratios during downturns. Secondly, Minsky's financial instability hypothesis argues that financial markets tend to experience periods of stability followed by periods of excess speculation (Minsky, 1992). As such, the CcLTV policies align with Minsky's theory by preventing credit expansion during periods of exuberance and limiting the accumulation of excessive debt.

3.1 Theoretical Literature

Bernanke and Gertler (1989) show how financial market shocks can have significant and persistent effects on the real economy through the financial accelerator channel**.** Existing market imperfections emanating from asymmetric information or moral hazard create a link between households and firms' financial health, borrowing capacity and credit in circulation and, subsequently, economic activity. The existence of this inverse relationship creates a channel through which otherwise short-lived economic shocks may have long-lasting effects (Bernanke, 2007). Furthermore, economic disturbances including all shocks that cause changes in the value of borrowers' liquid assets, illiquid assets, and outstanding obligations can induce the financial accelerator effect (Zidonyte, 2015). In this regard, CcLTV regulations recognise that borrowers may underestimate risks during housing market booms and overestimate risks during downturns. Thus, by introducing LTV ratios that reflect the changing risk environment, these behavioral patterns can be counteracted.

Aoki et al. (2004) argue that the financial accelerator effect on household spending operates in a way that a positive shock to economic activity increases the demand for housing. The increased demand raises the price of housing, which in turn increases households' borrowing capacity. The increased borrowing capacity stimulates the increase in housing demand thus amplifying the initial increase in housing prices. Moreover, the supply side of credit is affected through increased values of banks' assets. As the value of collateral rises, the likelihood of default on existing loans decreases. In this way, banks' assets become less risky and may encourage banks to extend lending to households. To augment this, Borio and Lowe (2002) highlight that increasing housing prices combined with a rapid growth of credit increase the probability of an episode of financial instability. Empirical studies have consistently shown that the effects of income shocks on housing pricing/or mortgage borrowing are larger in countries/cities and in periods where LTV ratios are higher, suggesting that the strength of a "financial accelerator" mechanism is positively associated with LTV ratios (Lamont and Stein (1999), Almeida et al. (2006), Lim et al. (2011)). Thus, imposing limits on LTV ratios might constrain this accelerator mechanism.

There is growing literature that seeks to model macroprudential policy in a DSGE framework**.** In the early 1970s, following the shortcomings of conventional macroeconomic models rooted in Keynesian economic theory, a need arose for a modelling technique immune to the Lucas critique (Ehelepola, 2016). To respond to this need, Kydland and Prescott (1982) made the paradigm shift by proposing a model where economic agents optimise their behaviour through intertemporal optimisation and rational expectations within a DSGE framework. Real shocks are embedded within these real business cycle models to create business cycle fluctuations, making them relevant for macroprudential policy analysis. In DSGE models, agents form expectations about the future based on all available information, leading to decisions that optimise their utility or profits over time (Chatelain and Ralf, 2018). The principle of intertemporal optimisation ensures households maximise their utility subject to budget constraints and firms maximise their profits subject to production technologies and resource constraints. The general equilibrium condition ensures all markets clear, with aggregate demand equating to aggregate supply across the economy.

One key addition to DSGE models is the incorporation of financial market frictions, which are essential for analysing the impact of LTV ratios. The idea of DSGE modelling of credit constraints in the housing market can be traced back to the work of Lacoviello (2015). Financial intermediation and credit constraints are modelled to capture the dynamics of borrowing and lending. These constraints determine the amount households and firms can borrow against their assets, directly influencing their consumption and investment behaviours. This led to a notable trend towards adopting dynamic models in assessing the impact of housing market developments on the business cycle (Iacoviello & Neri, (2009); and Christensen et.al. (2009); and Angelini et.al. (2011)).

It is, however, important to note that there is no "one-size-fits-all" approach available to mitigate systemic risk due to the heterogeneity that exists across financial markets. Arnold et al. (2012) argue that the limited theoretical work to lead macroprudential policy is challenging, and consequently regulators often rely on the experience of other jurisdictions for guidance on good practice. This suggests that the absence of a single approach to implementing LTV and/or CcLTV ratio might mean that different methods can be effective. Cagliarini (2016) adds that the lack of an analytical framework on the efficacy of macroprudential policy could weaken the use of LTV/CcLTV regulations.

3.2 Empirical Literature

Empirical literature on the impact of LTV ratios on financial stability exists in a number of ways and has generated a mixed array of inconclusive results. Empirical work consistent with the notion that CcLTV ratios play a crucial role in safeguarding financial stability include that of Cerutti et al. (2015) which explores the effects of the LTV ratio on real estate booms and busts in the Western Hemisphere, Asia Pacific, European, and African countries. The study finds that maximum LTV ratios linked to the real estate cycle appear to have the best chance to curb a boom. In analysing the effectiveness and drawbacks of the restrictions on LTV ratios, Wong et al. (2011) use econometric analysis of panel data covering 13 countries[6] and find maximum LTV ratios to be effective in reducing systemic risk stemming from fluctuations in property markets. Zidonyte (2015) analyses data from 2006Q1 to 2014Q1 using the generalised method of moments (GMM) model and finds that in Central Eastern Europe, the financial accelerator is evident when collateral constraints are tight,[7] with housing prices in the long run influenced by LTV ratios.

Almeida et.al. (2006) use the ordinary least squares and fixed effects methods to investigate the nexus between housing prices and demand for new mortgage borrowings. The study explores the features that characterise housing finance contracts and housing markets in 26 countries[8] for the period 1970 to 1992 to provide evidence supporting the financial accelerator. In particular, the study uses international variation in maximum LTV ratios to identify, within a group of constrained agents, those with more procyclical borrowing capacity. The results show that housing prices and new mortgage borrowings are more sensitive to aggregate income shocks in countries with higher maximum LTV ratios.

Using the DSGE model, Christensen and Meh (2011) examine the use of a CcLTV ratio on mortgage lending. The study incorporates a financial shock that raises the borrowing capacity

[6] Australia, Canada, Greece, Hong Kong, Korea, Malaysia, Philippines, Portugal, Singapore, Spain, Thailand, UK, US.

[7] Since the income-price sensitivity is increasing in the limits on LTV ratio.

[8] Australia, Belgium, Canada, Chile, Denmark, Finland, France, Germany, Hong Kong, Ireland, Israel, Italy, Japan, Korea, Malaysia, Netherlands, New Zealand, Norway, Sweden, Switzerland, Taiwan, Singapore, Spain, Thailand, UK, US.

of households and an aggregate productivity shock. In addition, the study operationalises the notion of a macroprudential response to the credit boom by assuming that the regulatory authority adjusts the LTV ratio in response to variables such as credit or housing prices. The findings showed that the financial shock leads to a significant rise in mortgage borrowing, implying that a reduction in the regulatory LTV ratio dampens the increase in debt and the expansion in housing prices and residential investment.

Jia (2019) assesses the effects of differentiated LTV ratios on house price growth in China over the period 2007 to 2016. The study employs the fixed effects model and uses a city-level panel data set that includes the house price index, and LTV caps. The findings reveal that the LTV policy is effective in dealing with increasing house prices as a tightening policy tends to exert a greater impact on house prices. Additionally, the study finds that the elasticity of urban housing supply affects the effectiveness of LTV policy. This suggests that trends in mortgage lending and house prices are affected not only by the LTV ratio but by various other factors such as taxation and the housing supply elasticity.

Liu and Molise (2019) investigate the impact of the CcLTV regulation in South Africa, where heterogeneous borrowers from distinct sectors of the credit market co-exist. The study uses quarterly data for the period 1994Q1 to 2016Q4 within a DSGE model to identify the optimal design of the CcLTV ratio in South Africa. The study considered a generic and sector specific policy regimes for the implementation of the CcLTV regulation[9] and finds that both regimes are effective in enhancing financial and macroeconomic stability.

In contrast to the studies supporting LTV ratios in curbing housing market imbalances, several studies document mixed evidence. For instance, Lim et.al. (2011) estimate the seemingly unrelated regressions to capture the impact between housing prices and financial stability for 36 countries[10] during two episodes.[11] The study rejects the hypothesis of LTV ratios in explaining crisis outcomes or pre-crisis booms. The study finds that LTV ratios explain neither the depth of the house price downturn nor the increase in loan losses during the crisis. However, when the sample includes only advanced economies and a prolonged estimation period from 1980 to 2010, the study finds evidence that LTV ratios explain house price movements.

[9] Under the generic regime, the authority adjusts the household and corporate LTV ratios to changes in aggregate credit and output; under the sector-specific regime, the authority adjusts those ratios according to their specific sectoral credit conditions and output, with different intensities.

[10] Western Hemisphere, Asia Pacific, European countries, and South Africa.

[11] The boom period (2004 - 2007) and the bust period (2008 - 2009).

Kronick (2014) evaluates whether the CcLTV ratio can be used to cool off a potentially overheated Canadian housing market. To examine the relationship between LTV ratios and residential mortgage credit in Canada, the study uses the Structural Vector Autoregressive (SVAR) model for a dataset covering the period 1981 to 2012. The results show that changes to the LTV ratio did not have significant effects on mortgage credit in three of the four LTV regulation changes: the 1992 loosening, 2006 loosening, and 2008 tightening. The study, however, finds that only the 1982 tightening had significant effects on mortgage credit contrary to expectations.

Summing up, despite the prevailing evidence on the use of the CcLTV ratio in tempering housing market imbalances, there is generally no consensus on its effectiveness. Although the findings are mixed, empirical evidence supports the effectiveness of CcLTV ratios in reducing financial vulnerabilities and dampening the amplitude of credit cycles. The mixed findings can be due to several reasons, including inter alia modelling techniques used, country specificities, and policymakers not focusing on the LTV ratio as a primary tool. This pinpoints the need for further research on the subject matter using structural and dynamic models. Additionally, the implication of the evidence contrary to a priori expectations of the CcLTV ratio towards housing market stabilisation, suggests that relying solely on the CcLTV ratio to mitigate housing market imbalances may not be sufficient. Thus, it is imperative to complement such measures with other policy tools, such as monetary policy. This, however, necessitates careful coordination and coherence of policies to ensure synergy.

4. The Model

This study employs a DSGE model to investigate the role of the CcLTV ratio in fostering financial and macroeconomic stability. The pioneer work of Lacoviello (2015) forms the basis for the model adopted by the study. The model considers an economy which comprises of two households (patient and impatient), entrepreneurs, the bank, and a macroprudential authority. The households supply labour and consume the final output and housing. Patient households are the surplus agents in the economy and provide the bank with savings deposits while impatient households are deficit agents in the economy. Borrowers are relatively impatient and have a higher propensity to consume, and resultantly, borrow from patient households in equilibrium through the banks. The impatient households use their housing as a collateral asset to secure credit from the bank. Impatient households face a collateral constraint which according to Kiyotaki and Moore (1997), Lacoviello (2005), and Christensen and Meh (2011) introduces a mechanism that amplifies the effects of shocks.[12]

In the model, entrepreneurs borrow funds from the bank to finance the production of output using household labour and housing as inputs. In equilibrium, households and entrepreneurs have different discount factors for their future utility. The bank mediates funds between the two households, and entrepreneurs. In addition, banks set interest rates on deposits and on loans to maximise profits. The bank's assets include loans to households and entrepreneurs, while liabilities are deposits and capital. Banks also face a balance sheet constraint of maintaining minimum capital requirements. The macroprudential authority is responsible for financial stability using the CcLTV regulation.

Although the constant LTV regulation is currently only applied to the residential real estate market,[13] this study focuses on two policy regimes where heterogeneous borrowers from distinct sectors (household and corporate) of the credit market co-exist.[14] This approach aims to assist the Bank in obtaining the optimal design of the CcLTV ratio regulation. This differs from studies that consider a single CcLTV regulation in a setting where there is only one type of borrower, or where there are homogeneous borrowers from one sector of the credit market.

4.1 Patient Households (Savers)

The representative patient household chooses real consumption ($C_{s,t}$), housing ($H_{s,t}$) and leisure (1-$N_{s,t}$) to maximise the expected discounted lifetime utility:

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

where E_0 and β_s ϵ (0; 1) are the expectation operator and the household's subjective discount factor, respectively. Consumption appears in the utility function relative to external habit formation, with η_s measuring the degree of habit persistence. The scaling factor (1-η_s) ensures that the marginal utility of consumption is independent of the habit parameter in the steady

[12] Primarily, the collateral constraint limits the borrower's ability to borrow to a fraction of the value of their housing assets.

[13] Residential real estate includes houses, apartments and other dwellings and any other associated land intended for occupancy by individual households (Financial Soundness Indicators, 2019).

[14] Under the generic regime, the authority adjusts the household and corporate LTV ratios to changes in aggregate credit and output, while under the sector-specific regime, the authority adjusts the LTV ratios according to their specific sectoral credit conditions and output, with different intensities.

state. j and τ are weights of housing and leisure in the utility function, respectively. A_t is the housing demand shock, which evolves according to the following law of motion:

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

where ρ_a represents the persistence of the shock. $\xi_{a,t} \sim$ *i.i.d.N*(0; σ_a^2) is a white noise process, normally distributed with zero mean and variance σ_a^2. The housing demand shock captures exogenous factors that shift the household's preference and demand for housing. As such, in each period, the household begins with housing stock ($H_{s,t-1}$) and savings deposits (D_{t-1}) coming to mature. Moreover, the household supplies labour to entrepreneurs and receives a real wage rate ($W_{s,t}$). $R_{d,t}$ is the real gross return on a one-period risk-free deposit and q_t is the relative price of housing (in units of consumption). The household's budget constraint is as follows:

$$C_{s,t} + D_t + q_t(H_{s,t}\text{-}H_{s,t-1}) = W_{s,t}N_{s,t} + R_{d,t-1}D_{t-1} , \quad \ldots (3)$$

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 the household’s problem are as follows:

$$1 = \beta_s E_t \frac{U_{Cs,t+1}}{U_{Cs,t}} R_{d,t} , \quad \ldots (4)$$

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

$$W_{s,t}, = \frac{\tau}{(1- N_{s,t})U_{Cs,t}} . \quad \ldots (6)$$

Equation (4) is the standard consumption Euler equation, while Equation (5) is for asset pricing (household’s demand for housing) and equates the marginal cost of housing to marginal benefit. For the household, the marginal benefit of housing is given by the direct utility benefit of consuming one extra unit of housing in units of consumption plus the present discounted value of housing. Equation (6) is the household's labour supply condition and equates the real wage rate to the marginal rate of substitution between consumption and leisure.

4.2 Impatient Households (Borrowers)

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

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

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

$$C_{b,t} + R_{b,t-1}L_{b,t-1} + q_t(H_{b,t}-H_{b,t-1}) = W_{b,t}N_{b,t} + L_{b,t} + \varsigma_{b,t}, \qquad \ldots (8)$$

where $L_{b,t}$ is the bank's loan to the household which accrues a real gross interest rate of $R_{b,t}$. $W_{b,t}$ is real wage rate for the household. An exogenous loan loss shock $\varsigma_{b,t}$ which is as a partial default by the household on its loan is introduced. For the household, a loan default is an indirect increase in wealth because by paying less than the contracted amount, the household can spend more than it anticipated. The same shock appears with a negative sign in the bank's budget constraint. The shock evolves according to the following law of motion:

$$\varsigma_{b,t} = \rho_{\varsigma}\varsigma_{b,t-1} + \xi_{\varsigma,t}, \qquad \ldots (9)$$

where ρ_{ς} represents the persistence of the shock. $\xi_{\varsigma,t} \sim$ *i.i.d.N*(0; σ_{ς}^2) is the white noise process, normally distributed with zero mean and variance σ_{ς}^2. The household faces a credit constraint that limits the amount borrowed to a fraction $m_{b,t}$ of the expected value of the housing:

$$L_{b,t} \leq m_{b,t}E_t\left(\frac{q_{t+1}}{R_{b,t}}H_{b,t}\right), \qquad \ldots (10)$$

$m_{b,t} \in (0,1)$ is the LTV ratio for the impatient household.

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 household's problem are:

$$1 = \beta_b\, E_t \frac{U_{Cb,t+1}}{U_{Cb,t}} R_{b,t} + \frac{\lambda_{b,t}}{U_{Cb,t}}, \qquad \ldots (11)$$

$$q_t = j\frac{A_t}{H_{b,t}\, U_{cb,t}} + \beta_b\, E_t\left(\frac{U_{Cb,t+1}}{U_{Cb,t}}\right)q_{t+1} + m_{b,t}\left(\frac{\lambda_{b,t}}{U_{Cb,t}}\right) E_t \frac{q_{t+1}}{R_{b,t}}, \qquad \ldots (12)$$

$$W_{b,t}, = \frac{\tau}{(1-N_{b,t})U_{Cb,t}}. \qquad \ldots (13)$$

Equation (11) represents the household's demand for a bank loan and differs from the standard Euler equation because of the borrowing constraint. Asset pricing Equation (12) for housing equates the marginal cost of housing to marginal benefit. For the household, the marginal benefit of housing is given by the direct utility benefit of consuming one extra unit of housing in units of consumption plus the present discounted value of housing. Equation (12) is the household's demand for housing while Equation (13) is the household's labour supply condition.

4.3 Entrepreneurs (Corporates)

Entrepreneurs produce final output (Y_t) using two types of household labour supply $(N_{s,t}\ and\ N_{b,t})$ and housing $(H_{e,t})$ as inputs. The entrepreneur maximises the expected discounted lifetime utility as:

$$E_0 \sum_{t=0}^{\infty} \beta_e^t \left[(1-\eta_e) \log(C_{e,t}-\eta_e C_{e,t-1})\right], \quad \ldots (14)$$

where $\beta_e < \beta_s$. $C_{e,t}$ is the entrepreneur's real consumption, which can be regarded as dividends. Consistent with literature (Liu et al., (2013)), $\eta_e C_{e,t-1}$ captures the dividend smoothing which is key in adequately explaining the movements between asset prices and real variables. The budget constraint for the entrepreneur is given by:

$$C_{e,t} + q_t(H_{e,t}- H_{e,t-1}) + R_{e,t}L_{e,t-1} + W_{s,t}N_{s,t} + W_{b,t}N_{b,t} = Y_t + L_{e,t} + \varsigma_{e,t}\ , \quad \ldots (15)$$

where $N_{s,t}$ and $N_{b,t}$ represent the patient and impatient households' labour supply, respectively. $L_{e,t}$ are the borrowed funds from the bank which accrues a real gross interest rate of $R_{e,t}$. $\varsigma_{e,t}$ captures an exogenous loan repayment shock. Like the impatient household's loan loss shock, the shock represents an indirect increase in wealth in the event of default. The shock evolves according to the following law of motion:

$$\varsigma_{e,t} = \rho_\varsigma \varsigma_{e,t-1} + \xi_{\varsigma,t}\ , \quad \ldots (16)$$

where ρ_ς represents the persistence of the shock. $\xi_{\varsigma,t} \sim$ *i.i.d.N*(0; σ_ς^2) is the white noise process, normally distributed with zero mean and variance σ_ς^2.

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

$$Y_t = Z_t \beta H_{e,t-1}^{v}[N_{s,t}^{1-\sigma} N_{b,t}^{\sigma}]^{1-v}, \quad \ldots (17)$$

where v ϵ (0; 1) is the elasticity of output with respect to housing and σ ϵ (0, 1) captures the impatient households' labour output share. Technology shock (Z_t) evolves according to the following law of motion:

$$\log(Z_t) = \rho_z \log Z_{t-1} + \xi_{z,t}\ , \quad \ldots (18)$$

where ρ_z represents the persistence of the shock. $\xi_{z,t}$ ~ *i.i.d.N*(0; σ_z^2) is the white noise process, normally distributed with zero mean and variance σ_z^2. The entrepreneur's borrowing constraint is:

$$L_{e,t} \leq m_{e,t} E_t(\frac{q_{t+1}}{R_{e,t+1}} H_{e,t}) \text{ .} \qquad \text{... (19)}$$

Equation (19) suggests that the total amount of credit the entrepreneur can secure from the bank cannot exceed a fraction $m_{e,t}$ of the expected market value of the entrepreneur's collateral assets. $m_{e,t}$ ϵ (0,1) represents the LTV ratio for the entrepreneur (the corporate LTV ratio).

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. The first order conditions which define the entrepreneur's problem are:

$$q_t = \beta_e E_t(\frac{U_{Ce,t+1}}{U_{Ce,t}})(v\frac{Y_{t+1}}{H_{e,t}} + q_{t+1}) + m_{e,t}(\frac{\lambda_{e,t}}{U_{Ce,t}}) E_t \frac{q_{t+1}}{R_{e,t+1}} \qquad \text{... (20)}$$

$$W_{s,t}, N_{s,t}, = (1-\sigma)(1-v) Y_t \text{ ,} \qquad \text{... (21)}$$

$$W_{b,t}, N_{b,t}, = \sigma(1-v) Y_t \text{ ,} \qquad \text{... (22)}$$

$$1 = \frac{\lambda_{e,t}}{U_{Ce,t}} + \beta_e E_t \frac{U_{Ce,t+1}}{U_{Ce,t}} R_{e,t+1} \text{ .} \qquad \text{... (23)}$$

Equation (20) represents the entrepreneur's demand for housing. It equates the marginal cost of one extra unit of housing (price of housing) to its marginal benefits. For the entrepreneur, the marginal benefits of housing are given by the present discounted value of the next period's real return on housing plus the benefit of housing as a collateral asset for securing credit. The entrepreneur's real return on housing is given by the marginal product of the housing and the future resale value of the housing. Equation (21) and (22) are labour demand conditions. Equation (23) is the asset pricing equation for the entrepreneur's demand for credit.

4.4 The bank

The bank is a financial intermediary that mediates funds between patient households, impatient households, and entrepreneurs. The representative bank chooses real consumption $C_{f,t}$ to maximise the expected discounted lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta_f^t \, [(1-\eta_f) \, log(C_{f,t}-\eta_f C_{f,t-1}), \qquad \text{... (24)}$$

where β_f is the bank's subjective discount factor. $C_{f,t}$ represents the dividend payments from the bank, which are assumed to be fully consumed by the bank, and $\eta_f C_{f,t-1}$ represents some form of dividend smoothing. The bank's budget constraint is given by:

$$C_{f,t} + R_{d,t-1}D_{t-1} + L_{b,t} + L_{e,t} + AC_{bf,t} + AC_{ef,t} = D_t + R_{b,t-1}L_{b,t-1} + R_{e,t}L_{e,t-1} - \varsigma_t \,, \qquad \ldots (25)$$

where D_t is the household's deposits. $L_{b,t}$ *and* $L_{e,t}$ are bank lending to impatient households and entrepreneurs, respectively. $AC_{bf,t} = \frac{\emptyset_{bf}}{2}\frac{(L_{b,t}-L_{b,t-1})^2}{L_b}$ and $AC_{ef,t} = \frac{\emptyset_{ef}}{2}\frac{(L_{e,t}-L_{e,t-1})^2}{L_e}$ are quadratic loan portfolio adjustment costs associated with household and entrepreneur loans, respectively. $\varsigma_t = \varsigma_{b,t} + \varsigma_{e,t}$ is the loan repayment shock. This represents loan losses that the bank incurs when impatient households and entrepreneurs default on their loans. From the bank's perspective, loan losses also represent a shock to their net worth. An increase in loan losses reduces the bank's profits and impairs its balance sheet. This results in a decline in the bank's capital. The bank is also subject to capital requirements in line with the Bank's capital adequacy requirements. Let $BK_t = L_t - E_t\varsigma_{t+1} - D_t$ be the bank's capital. The capital requirement constraint is given by:

$$\frac{L_t - E_t\varsigma_{t+1} - D_t}{w_b(L_{b,t} - E_t\varsigma_{b,t+1}) + w_e(L_{e,t} - E_t\varsigma_{e,t+1})} \geq k \,, \qquad \ldots (26)$$

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

$$D_t \leq (1-w_e k)\left(L_{e,t} - E_t\varsigma_{e,t+1}\right) + (1-w_b k)\left(L_{b,t} - E_t\varsigma_{b,t+1}\right). \qquad \ldots\ldots(27)$$

Equation (27) states that the amount that the bank can take as a deposit from households cannot exceed a weighted sum of the bank's assets net of the expected loan losses, where the weights on the two classes of the bank's assets are given by (1- w_ik) for all $i = \{b, e\}$. The capital requirement constraint limits the extent to which the bank can take on leverage. The assumption is that the bank is more impatient than the patient household; that is $\beta_f < \beta_s$, ensures that the borrowing constraint Equation (27) is binding in 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. The bank's optimal condition for deposits and credit to households and entrepreneurs are given by:

$$\beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} R_{d,t} = 1 - \frac{\lambda_{f,t}}{U_{Cf,t}}, \qquad \text{… (28)}$$

$$\beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} R_{b,t} = 1 - (1-w_b k) \left(\frac{\lambda_{f,t}}{U_{Cf,t}} \right) + \frac{\emptyset_{b,f}}{L_b} (L_{b,t} - L_{b,t-1}), \qquad \text{… (29)}$$

$$\beta_f E_t \frac{U_{Cf,t+1}}{U_{Cf,t}} R_{e,t+1} = 1 - (1-w_e k) \left(\frac{\lambda_{f,t}}{U_{Cf,t}} \right) + \frac{\emptyset_{e,f}}{L_e} (L_{e,t} - L_{e,t-1}), \qquad \text{… (30)}$$

The banks' demand for deposits, Equation (28) equates the current pay-off from taking one extra unit of deposit from the patient household to the discounted cost of raising such deposits. Equations (29) and (30) equate the present discounted pay-off providing one extra unit of credit to the cost of providing such credit.

From Equations (28) to (30), the evolution of interest rate spreads is given by:

$$R_{b,t} - R_{d,t} = \frac{1}{\beta_f} E_t \frac{U_{Cf,t}}{U_{Cf,t+1}} = [w_b k \left(\frac{\lambda_{f,t}}{U_{Cf,t}} \right) + \frac{\emptyset_{b,f}}{L_b} (L_{b,t} - L_{b,t-1})], \qquad \text{… (31)}$$

$$R_{e,t+1} - R_{d,t} = \frac{1}{\beta_f} E_t \frac{U_{Cf,t}}{U_{Cf,t+1}} = [w_e k \left(\frac{\lambda_{f,t}}{U_{Cf,t}} \right) + \frac{\emptyset_{e,f}}{L_e} (L_{e,t} - L_{e,t-1})], \qquad \text{… (32)}$$

In the steady state, Equations (4) and (28) suggest that the bank's borrowing constraint and the capital requirement constraint holds with equality as long as $\beta_f < \beta_s$.

4.5 Macroprudential Authority

The authority uses the CcLTV regulation as its macroprudential policy tool by adjusting the LTV ratio to changes in credit and output in a countercyclical manner. The CcLTV regulations requires the authority to adjust the LTV ratios in response to indicators of financial vulnerability. The CcLTV regulation requires the authority to decrease the LTV ratios during an upswing of the business and credit cycle, thus tightening the borrowing constraints and restraining credit growth and leverage in the credit-dependent sector. During a downswing of the cycle, the regulation requires the authority to increase the LTV ratios, thus relaxing the borrowing constraints to encourage credit growth. This way, the authority prevents excessive fluctuation in credit and contain the build-up of systemic risk in the financial sector and the spillover of financial vulnerabilities to the real sector. The study considers both the generic and sector specific CcLTV policy regimes. Under the generic regime, the authority does not differentiate between the two credit market sectors and adjusts both household and corporate LTV ratios to changes in aggregate credit and output as follows: a sector specific market where the authority adjusts the household LTV ratios to changes in aggregate credit and output as follows:

$$m_{i,t} = m_i \left(\frac{L_t}{L}\right)^{-X_{l,m_i}} \left(\frac{Y_t}{Y}\right)^{-X_{y,m_i}} \;, \forall_i = \{b, e\} \;, \qquad \ldots (33)$$

where m_i is the steady-state value of the LTV ratio, L and Y are the steady state values of aggregate credit and output, respectively. $X_{l,m_i} \geq 0$ and $X_{y,m_i} \geq 0$ measure the response of the LTV ratios to deviations of credit and output from their steady states, respectively.

4.6 Market equilibrium conditions

The economy's aggregate resource constraint becomes:

$$Y_t = C_{s,t} + C_{b,t} + C_{e,t} + C_{f,t} + Adj_i \;, \qquad \ldots (34)$$

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

The housing market clearing condition requires:

$$H_{s,t} + H_{b,t} + H_{e,t} = 1 \;. \qquad \ldots (35)$$

The aggregate supply of credit is given by:

$$L_t = L_{b,t} + L_{e,t} \;. \qquad \ldots (36)$$

5. Calibration

The model is calibrated to the Namibian economy using quarterly data for the period 2000Q1 to 2023Q4. The study uses the following variables, household mortgage credit, corporate mortgage credit, aggregate credit, real GDP, house prices, household consumption, household deposits, prime lending rate, and the maximum LTV ratios for households, and businesses.[15] The parameters in the model are calibrated using real data to match the steady state ratios of the variables to aggregate output, and other parameters are adopted from literature (Liu and Gupta, (2007); Lambertini et al., (2013); Liu and Molise, (2019)).

Table 1 presents the calibrated parameters for the model. The discount factor for patient households is set at β_s = 0.98, while impatient households' and entrepreneurs' discount factors are set at $\beta_b = \beta_e$ = 0.96. The weight on leisure in the households' utility function is set at τ =

[15] The maximum LTV ratio for the households is the current applicable LTV ratio as set by the Bank, and the maximum LTV ratio for corporates is a proxy for the LTV ratio applicable for corporates as set by the banks.

1, in line with literature. The impatient household's labour income share is calibrated at σ = 0.43 using real data on the compensation of employees in relation to output.[16] Habit persistence for all agents is set at n_i = 0.7, which is broadly in line with literature (Christensen and Meh, 2011). The bank's loan portfolio adjustment cost parameters are set at $\emptyset_{b,f}$ = 0.25 and $\emptyset_{e,f}$= 0.05 for household loans and entrepreneur loans, respectively.

The share of housing in production is set at v = 0.10, which is commonly used in the literature for emerging market economies (Lacoviello & Minetti, (2006); Liu and Molise (2016)). Based on calibration of Liu and Molise (2016), the housing weight in the utility functions is set at j = 0.10. The LTV ratio for impatient households is set at m_b= 0.90. This value is consistent with the maximum down-payment that the Namibian banks require for providing home loans for residential purposes. Although the Bank has not established an LTV ratio for the corporate sector, the model incorporates an LTV ratio of m_e= 0.70, which reflects the internal standard applied by Namibian banks when extending mortgage loans to corporates. This value aligns with the calibrated values for the South African economy.

Table 1: Calibrated parameters

Parameter	Symbol	Value	Parameter	Symbol	Value
Discount factor (patient household (HH))	β_s	0.98	Impatient HH's income share	σ	0.43
Discount factor (impatient HH)	β_b	0.96	Labor supply parameter	τ	1
Discount factor (Entrepreneur)	β_e	0.96	Loan to HH adj. cost, bank	$\emptyset_{b,f}$	0.25
Discount factor (bank)	β_f	0.91	Loan to Entrep. adj. cost, Bank	$\emptyset_{e,f}$	0.05
Habit persistence, $\boldsymbol{i = b, s, e. f}$	η_i	0.70	Risk weight (Impatient HH's loan)	w_b	1
Housing preference	j	0.10	Risk weights (Entrep. loan)	w_e	1
Steady state LTV ratio, impatient HH	m_b	0.90	Autocorr. technology shock	ρ_z	0.95
Steady state LTV ratio, Entrep.	m_e	0.70	Autocorr. housing demand shock	p_a	0.97
Steady state capital requirement ratio	k	0.105	Autocorr. financial (loan loss) $i = \{b, e\}$	$\rho_{\varsigma i}$	0.90
Housing share in production	v	0.05			

Source: BoN

The bank's capital requirement ratio is set at k= 0.105, which represents the average capital ratio requirement during the study period. This value accounts for changes in capital requirements, including adjustments made during the Covid-19 pandemic, when the Bank

[16] The compensation of employees to output data was obtained from Namibia's National Accounts.

temporarily reduced capital requirements to support financial stability. 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 $\beta_f = 0.91$. This value is lower than the patient households' discount factor (β_s), which satisfies the condition required for the capital requirement constraint to hold with equality in steady state. Together with the impatient households' and entrepreneurs' discount factors, these values also guarantee that impatient households' and entrepreneurs' borrowing constraints are binding in the steady state. Finally, the autocorrelation coefficients for technology and housing demand shocks are set at $\rho_z = 0.95$ and $\rho_a = 0.97$ respectively, consistent with Liu and Gupta (2007) and Gupta and Sun (2016). The choice of a highly persistent housing demand shock is also consistent with the DSGE literature (Lambertini et al. (2013); and Lacoviello (2015)) among others. The persistence of the financial (loan loss) shock is set at $\rho_{\varsigma i} = 0.90$ based on literature estimates (Lacoviello (2015), and Liu & Molise (2019)).

6. Results

6.1. Business cycle properties

This section assesses the models of the constant LTV and CcLTV policy regime's ability to reproduce the stylized facts of the Namibian data observed over the period 2000Q1-2023Q4. Table 2 shows the standard deviations of the main variables and their correlations with output as derived by the model and as calculated from the data. Models 1 and 2 show the standard deviations and correlations generated by the constant and the CcLTV regimes following a technology shock.

Table 2: Business cycle properties

Variable	Standard deviation %			Correlation with output		
	Data	Model 1	Model 2	Data	Model 1	Model 2
Real GDP	4.46	1.53	1.57	1	1	1
Household Consumption (HHC)	6.63	1.53	1.57	95.3	1	1
Household Mortgage Credit (HMC)	7.04	1.39	0.09	92.1	80.79	72.11
House Prices (HP)	5.93	8.71	8.71	90.4	96.42	94.57
Mortgage Rate (MR)	0.72	0.28	0.29	3.3	-68.30	-69.95
Household Deposit (HD)	6.03	2.49	2.96	96.0	92.82	94.32

Note: Except for the lending rates, all variables are detrended using the Hodrick-Prescott (HP) filter. Data is obtained from the Bank of Namibia and National Statistic Agency.
Source: Authors compilation

The results indicate that while Model 1 captures the cyclical moments of the real sector, the moments generated by the model are lower compared to those observed in the data. The model underestimates the volatility of output, household consumption, and household loans in comparison to the data. Consistent with the data, the model generates higher volatility of house prices compared to output. The model reflects similar volatility levels for household consumption and output which contrasts the volatility levels observed in the real data. Model 1 reproduces the positive correlation between consumption, and house prices, with output, although it overstates these correlations. Model 2 generates similar results as in the case of model 1 except for the volatility of the household mortgage credit.

The banking sector cyclical dynamics (financial sector indicators) are not well captured by both models. The models are able to reproduce the standard deviations of household deposits and household loans, although lower compared to the data. Consistent with the data, the models accurately reflect that these variables are more volatile than output, except for household loans which are less volatile. Additionally, the models replicate the pro-cyclicality of deposits and household mortgage loans. Despite the overestimation, the models better mirror the negative correlation between output and the mortgage lending rate which contrasts the positive relationship observed in the data. Considering its simplicity and the technology shock applied, the models demonstrate a reasonable alignment with the initial data observations.

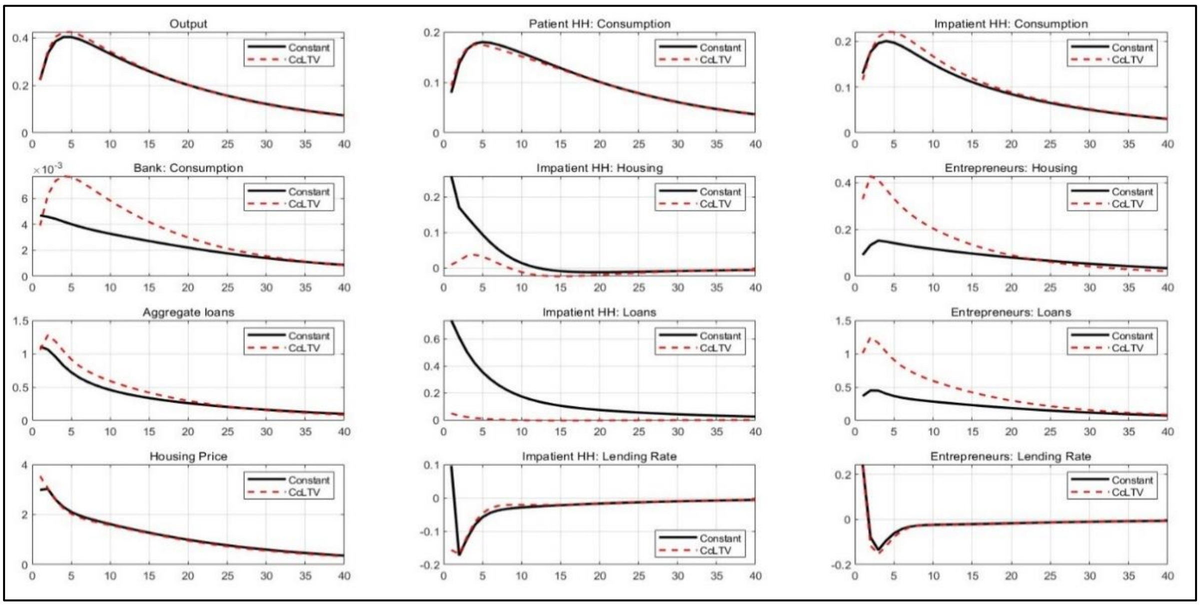
6.2. Impulse response functions

To investigate the effectiveness of the sector specific CcLTV regime and the transmission mechanisms through which the macroprudential authority achieves the objective of the macroprudential policy, the study simulates the impulse responses of the main variables following technology, financial and housing demand shocks. The study compares the baseline regime which is defined by constant LTV ratios in equations (11) and (20) with the optimal sector-specific CcLTV regime.

6.2.1. Technology shock

The impulse response functions (IRFs) in Figure 3 suggest that a technology shock has significant and positive short-term effects on output, consumption, and loans. Compared to the constant LTV regime, the CcLTV regime leads to more pronounced short-term reactions.

Figure 3: Impact of a positive technology shock



Source: Authors compilation

In response to a positive technology shock, the constant regime shows an expansionary effect across the economy. The positive technology shock leads to a significant increase in output, which peaks shortly after the shock and gradually returns to its steady state. This aligns with Christiano, Eichenbaum, and Evans (2005), who highlight that technology shocks typically enhance productivity and output in the short term. Patient households' consumption increases and follows a similar pattern to output. On the other hand, impatient households, who are more sensitive to changes in income and credit conditions, experience a slightly higher peak in consumption, reflecting Jermann and Quadrini's (2012) finding that different household types respond differently to credit conditions and economic shocks. The positive technology shock further boosts banks consumption, driven by improved profitability. Loans to entrepreneurs and impatient households surge initially due to increased credit demand and gradually return to pre-shock levels. The housing demand by entrepreneurs and impatient households initially spikes; however, entrepreneurs' demand shows a sustained increase while the demand by impatient households falls back to steady state levels more rapidly. House prices also increase sharply, driven by the heightened housing demand, and then decline slowly. Aggregate mortgage loans increase significantly in response to increased credit demand, and this coincides with the pattern observed for mortgage loans extended to entrepreneurs and impatient households.

Similar to the constant LTV regime, the technology shock also results in expansionary effects for the CcLTV regime, although the responses of key variables differ. Output increases initially but reaches a slightly higher peak and returns to its steady state more rapidly than in the constant LTV regime. This aligns with Bernanke, Gertler, and Gilchrist (1999), who argue that flexible credit conditions can result in different variable dynamics compared to more rigid financial regulations. The consumption of impatient households experiences a higher peak and remains elevated for an extended period compared to the constant regime. This suggests that impatient households are less constrained, which is aligned with the findings of Jermann and Quadrini (2012). The impact of the technology shock on lending rates are short lived and turned into negative before converging back to steady state in a very short period of time. This leads to a significant and sustained increase in entrepreneurs' loans and housing demand, highlighting that credit conditions are less restrictive. As a result, the bank's consumption experiences a significant and sustained increase, which surpasses the levels observed under the constant regime. This significant increase in bank's consumption is primarily due to increase in loans to entrepreneurs which is wealth enhancing for the banks. Aggregate loans also experience an increase and remain above the constant case mainly due to an increase observed under the entrepreneur loans. While house prices increase similarly in both regimes, the CcLTV regime does not significantly dampen the aggregate housing market's response to the shock.

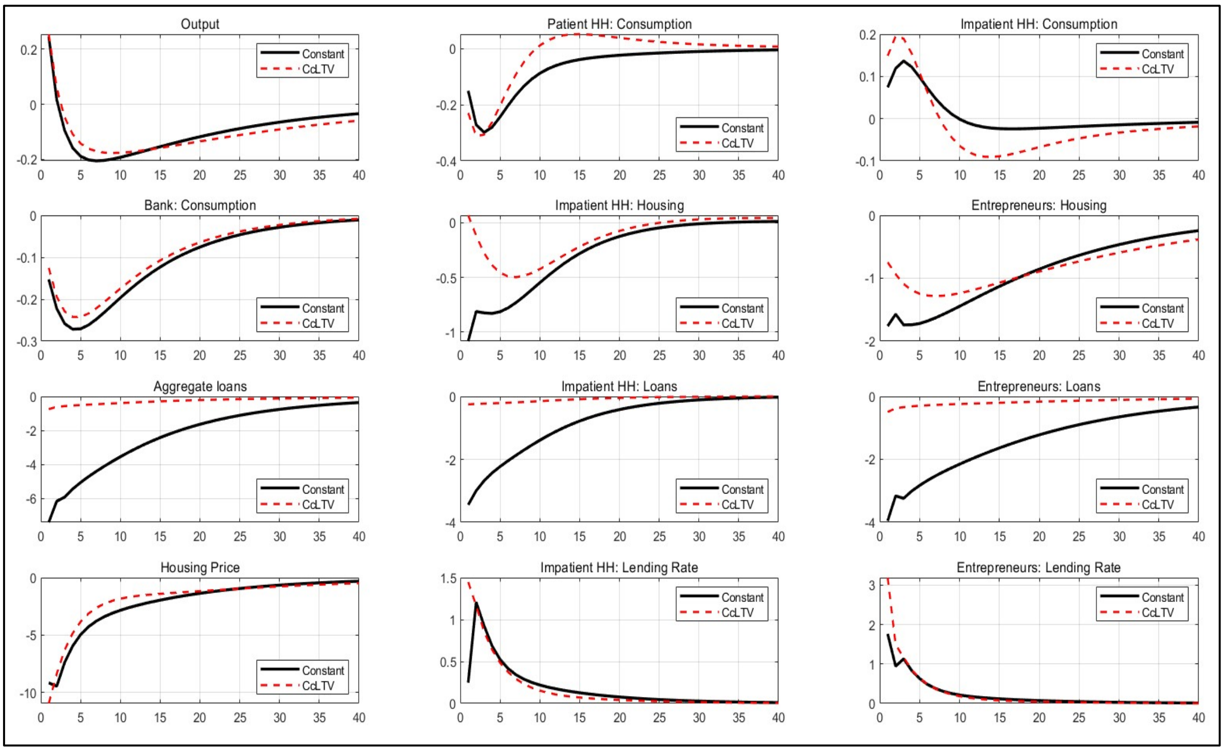
Overall, the two regimes exhibit different responses to a positive technology shock. The constant LTV regime provides a more balanced outcome by reducing the volatility of both real and financial variables except for impatient housing and loans. Conversely, under the CcLTV regime, stronger and more prolonged increases are observed in certain variables, particularly in impatient household consumption, bank consumption, and loans to entrepreneurs. This indicates that while the CcLTV regime moderates' output and house prices to some extent, it allows more flexibility in credit markets and household consumption. This difference suggests that the CcLTV regime redistributes the effects of the technology shock, allowing greater credit growth and consumption among specific economic agents, compared to the more uniform dampening seen in the constant regime.

In summary, the findings of Liu and Molise (2019) reinforce the notion that while the CcLTV regime moderates certain aspects of economic volatility, it also allows for more dynamic responses in the housing market and credit cycles. Both regimes manage the impacts of the shock, the constant regime does so in a more uniform manner, whereas the CcLTV regime introduces flexibility that results in divergent outcomes across different sectors of the economy.

6.2.2. Financial (household loan loss) shock

Figure 4 shows the IRFs of the variables of interest to a negative loan repayment shock. This shock represents loan losses that the bank incurs when impatient households and entrepreneurs default on their loans. Under the constant LTV regime, the financial shock negatively impacts the bank's balance sheets, reducing its net worth as evidenced by the sharp initial drop in bank consumption. This reduction in net worth tightens capital constraints, prompting banks to curtail credit supply to both impatient households and entrepreneurs. The reduction in credit availability directly dampens housing demand, particularly for impatient households who are more reliant on borrowing. To recapitalise and strengthen capital positions, banks raise lending rates which further discourages borrowing and investment. This leads to reduced credit demand, lower consumption, and a prolonged recession, as reflected in the slow recovery of output and consumption across various sectors. Entrepreneurs face a steep decline in loans, reflecting tightened borrowing conditions. The drop in house prices further limits the borrowing capacity of both impatient households and entrepreneurs by reducing the collateral value, causing a decline in housing demand. Overall, there is a decrease in aggregate loans as both household and corporate credit falls sharply.

Figure 4: Impact of a negative financial shock



Source: Authors compilation

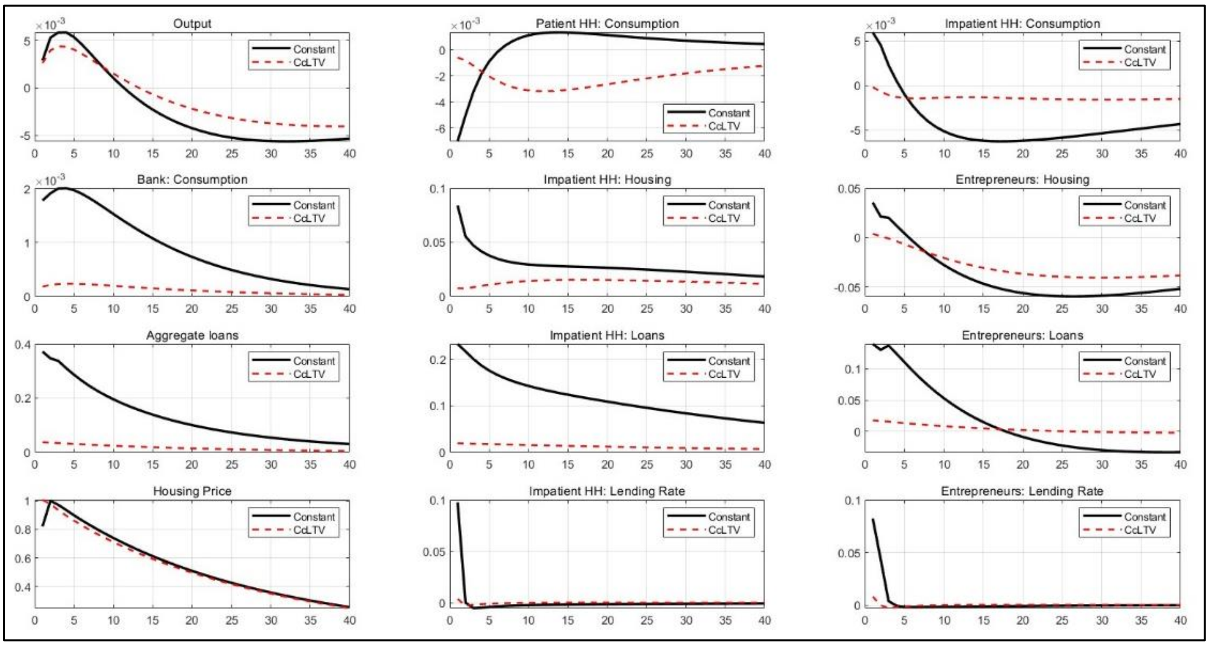
Under the CcLTV regime, the negative loan loss shock also triggers an initial decline in output, but it is somewhat less severe compared to the constant LTV regime. The credit tightening effect is dampened due to the presence of the CcLTV regulation. The bank's consumption, while still decreasing, falls by less than under the constant regime. Patient households' consumption initially drops but recovers more quickly compared to the constant LTV regime. Impatient household consumption experiences a higher increase in consumption following the negative loan loss shock indicating the fact the CcLTV affects the consumption of different agents asymmetrically. Aggregate loans remain largely flat across the horizon, reflecting the stabilising effect of the CcLTV regulation on credit conditions. Similarly, the increase in lending rates is mitigated under the CcLTV regime, and house prices do not drop as dramatically, thus maintaining more stable collateral values. Comparing the two regimes, the CcLTV regime is more effective in stabilising both real and financial variables in response to the negative loan loss shock.

In summary, the CcLTV regime proves to be more effective in dampening the negative impact of the loan loss shock across most variables compared to the constant regime. It mitigates the contractionary effects on output, consumption, loans, and house prices by providing a countercyclical policy buffer that prevents excessive tightening of credit conditions. The stabilisation of house prices under the CcLTV regime, through its countercyclical adjustments, plays a crucial role in maintaining collateral values and moderating credit contraction. This helps reduce the amplification effects typically seen under the financial accelerator mechanism (Bernanke et al., 1999), where declines in asset prices lead to further credit tightening. The policy reduces the volatility of both real and financial variables, in line with findings in the literature, such as those by Rubio and Carrasco-Gallego (2014) and Ravn (2016), which highlight the effectiveness of countercyclical macroprudential policies in stabilising the economy against adverse shocks.

6.2.3. Housing demand shock

Figure 5 shows the IRFs of the variables of interest following a positive housing demand shock. Under the constant LTV regime, a positive housing demand shock initially boosts house prices, leading to a rise in collateral value for both impatient households and entrepreneurs. This increase in collateral enhances borrowing capacity, resulting in higher levels of loans for both economic agents. The overall impact on output is positive but diminishes over time as consumption adjusts. Bank consumption experiences an increase due to higher lending activity and interest earnings. However, the lending rate for both entrepreneurs and households initially spike before converging back to the steady-state level, reflecting adjustments in risk premia and borrowing costs.

Figure 5: Impact of a positive housing demand shock



Source: Authors compilation

Under the CcLTV regime, the initial effects of a positive housing demand shock are more contained. The rise in house prices is less pronounced compared to the constant regime, suggesting that the CcLTV policy dampens the surge in demand for housing assets. As in the negative loan loss shock, loans extended to both entrepreneurs and impatient households remain largely flat across the horizon, reflecting the stabilising effect of the CcLTV regulation on credit conditions. As a result, the aggregate loans show a more subdued response as the CcLTV rule tightens borrowing constraints when house prices increase, preventing an excessive increase in credit. Impatient households experience a lower decline in consumption compared to the constant regime, as their debt servicing costs remain lower due to reduced borrowing. Furthermore, the combination of lower lending rates and stabilised aggregate loans under CcLTV reduces bank revenue, which leads to the observed decrease in bank consumption in comparison to the constant case. When comparing the two regimes, the constant LTV regime allows for a larger and more prolonged increase in house prices, credit growth, and consumption due to a positive housing demand shock. In contrast, the CcLTV regime curbs these expansions, resulting in smaller fluctuations in both real and financial variables.

Overall, the CcLTV regime effectively dampens the expansionary effects of a positive housing demand shock, leading to lower fluctuations in both house prices and aggregate loans compared to the constant LTV regime. The constant LTV regime permits more pronounced credit growth, which could potentially exacerbate financial vulnerabilities. The findings align with literature that highlights the stabilising role of countercyclical macroprudential policies in mitigating the build-up of systemic risk during periods of elevated housing market activity (Kuttner and Shim, 2016). This suggests that a CcLTV policy can serve as a crucial tool for containing credit booms and maintaining financial stability in the face of housing market shocks.

6.3. Efficiency Policy Frontier (EPF)

The present study determines the optimal rule for the CcLTV and the effectiveness of such policy in fostering financial and macroeconomic stability,

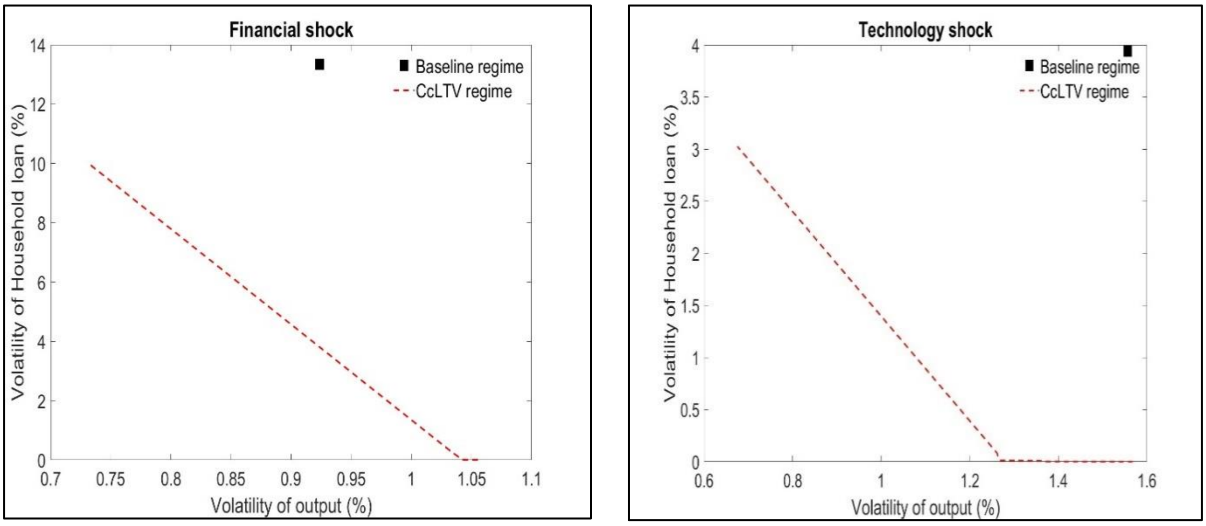
$$\mathcal{L}_{mp}=\lambda\sigma^2{}_{lb} + 1 - \lambda\sigma^2{}_{y} \ , \qquad \ldots (37)$$

where $\sigma^2{}_{l}$ and $\sigma^2{}_{y}$ are the unconditional variances of credit and output, respectively. The parameter λ represents the weight in the loss function. The loss function (37) implies that the macroprudential authority strives to achieve a balanced trade-off between financial stability measured by the volatility in credit and macroeconomic stability (measured by volatility in output). The study conducts experiments with the weights $\lambda = 0.8, \text{and } 1 - \lambda =$ 0.2. The assigned weight on output is smaller than that on credit, reflecting the fact that the primary objective of macroprudential policy is financial stability. The optimal policy parameters ($X^*{}_{l,j}$,$X^*{}_{y,j}$), for all $\{m_b, m_e\}$ are also derived.

The EPF presents the outcome of the trade-off between household loans and output volatility for the financial and technology shock. The EPF for the CcLTV regime shows the locus of the volatility of household loans and output calculated at each set of optimal policy coefficients that are obtained for different combinations of loss function weights.

To perform the exercise, the weight on household loans and output are allowed to vary within the range of λ [0,1]. For each combination of the loss function weights, the study computes the set of optimal policy coefficients that yields the lowest welfare loss and then plot the corresponding volatility of household loans and output in a two-dimensional plot, as shown in Figure 6. Moving from left to right in Figure 6, the weight on the volatility of household loans increases from 0 to 1 while that on the volatility of output decreases from 1 to 0.

Figure 6: Financial and Technology shock



Source: Authors compilation

Under the financial shock, also referred to as the household loan loss shock, the CcLTV regime demonstrates a superior ability to manage household loan volatility in comparison with the baseline regime. The EPF for the baseline regime (black square) indicates a relatively high volatility, particularly in household loans, with volatility levels ranging between 12 and 14 percent.

This is due to the fact that the baseline regime does not attempt to balance the trade-off between financial and macroeconomic stability as shown in Equation 33. However, the EPF under the CcLTV regime (red dashed line) illustrates a distinct trade-off between financial stability and macroeconomic stability. As the weight shifts from prioritising output stability to reducing loan volatility, the CcLTV regime demonstrates its ability to minimise financial instability effectively. In as much as the CcLTV minimises the volatility in household loans it comes at a cost of macroeconomic instability (Figure 6). The findings from the efficiency policy frontier under the financial shock suggest that to maximise financial stability benefits, the authority should set the relative weight at 0.85. Increasing the weight beyond this point does not provide further reductions in household loan volatility; instead, it leads to greater macroeconomic instability, as evidenced by the increase in output volatility. As such, policymakers need to carefully consider the balance between financial and macroeconomic objectives, as efforts to stabilise one aspect of the economy may have adverse effects on another.

Under the technology shock as shown in Figure 6, the CcLTV regime also allows for better overall outcomes than the baseline regime. The baseline regime under the technology shock shows an unfavourable position for both financial and macroeconomic stability when compared to the financial shock scenario. However, the CcLTV efficiency policy frontier for the technology shock demonstrates a more balanced trade-off between these two aspects of stability, as reflected by the EPF's negative 45-degree slope. Moreover, similar to the financial shock, increasing the weight beyond 0.75 does not result in further reductions in household loan volatility; instead, it leads to greater macroeconomic instability, as evidenced by the increase in output volatility. This highlights that the CcLTV regime remains effective even when facing different types of shocks.

6.4. Welfare analysis

This section presents the computed welfare in consumption equivalence for each agent in the model, with social welfare defined as the weighted sum of the individual agent welfare. In order to make the results more intuitive, welfare changes are presented in terms of consumption equivalents. The consumption equivalent measure denotes the constant fraction of consumption that households would need to forgo in order to obtain the benefits of implementing the CcLTV regime. A positive value in Table 3 indicates that the CcLTV regime is welfare-enhancing, while a negative value suggests it reduces welfare compared to the constant LTV case.

Table 3: Welfare

Variables	Technology Shock	Financial shock	Housing Demand
Social Welfare	-2.6218e-05	0.0036	-2.6453e-05
Patient households	6.0737e-04	-0.0132	7.4759e-04
Impatient households	-6.4580e-04	-0.0109	-5.9547e-04
Entrepreneurs	-0.0038	8.3442e-04	-0.0030
Banks	0.0016	0.0486	0.0011

Source: Authors compilation

The welfare differences across agents under the technology and housing demand shocks reveal similar patterns of gains and losses across banks, borrowers, savers, and entrepreneurs. The CcLTV regime benefits patient households and banks during these shocks, aligning with Lacoviello's (2005) argument that looser collateral constraints enhance borrowing capacity and investment, favouring wealthier agents and financial institutions. In contrast, impatient borrowers experience welfare losses under the CcLTV regime, which echoes Kiyotaki and Moore's (1997) finding that relaxed credit constraints heighten financial risks for more leveraged agents, who tend to prefer the stability provided by the constant regime. Entrepreneurs also face welfare losses in the CcLTV regime under both technology and housing demand shocks. As Liu, Wang, and Zha (2013) highlight, entrepreneurs are more sensitive to fluctuations in collateral value, making the constant regime more appealing to them by offering stability and reducing exposure to financial volatility. Thus, while patient households and banks gain from the CcLTV regime, impatient households and entrepreneurs generally find the constant regime more favourable due to its stabilising effects on welfare and financial risk.

In contrast, the financial shock presents a distinct pattern, where banks and entrepreneurs experience welfare gains, while both patient and impatient households face welfare losses. The substantial welfare gain for banks under the financial shock supports the literature's emphasis on how credit relaxation policies can bolster financial sector profitability, even as other agents, like borrowers and savers, may face losses (Dell'Ariccia, Laeven & Suarez, 2017).

The relatively neutral impact on social welfare, with a slight preference for the constant LTV regime except when faced with a financial shock, aligns with Justiniano, Primiceri, and Tambalotti's (2019) findings. The study suggests that while looser constraints can provide short-term gains, long-term stability and welfare are often better served through tighter credit controls. In summary, patient households (savers) and banks benefit from the CcLTV regime, while impatient households (borrowers) and entrepreneurs find the constant LTV regime more favourable due to its stabilising effects on welfare and reduced financial risk exposure.

7. Conclusion

This paper compares the performance of the constant LTV and CcLTV regimes in promoting financial and macroeconomic stability. The impulse response functions demonstrate that while the constant LTV regime provides uniform responses to a positive technology shock, the CcLTV regime offers flexibility, resulting in differentiated outcomes across economic sectors. Furthermore, under financial shocks, the CcLTV regime proves to be more effective in mitigating the adverse effects of loan loss shocks on most variables. In the case of housing demand shocks, the CcLTV regime demonstrates its ability to dampen expansionary effects, reducing fluctuations in house prices and aggregate loans compared to the constant LTV regime. The EPFs underscore the trade-offs between financial stability and macroeconomic objectives. Under financial shocks, the CcLTV regime effectively minimizes financial instability as policymakers shift their focus toward household loan volatility. However, during technology shocks, the trade-off between output and financial stability remains more balanced under the CcLTV regime.

In terms of the welfare analysis, which was computed using the consumption equivalent, the study finds that patient households (savers) and banks benefit from the CcLTV regime, particularly during technology and housing demand shocks, while impatient households (borrowers) and entrepreneurs experience welfare losses due to increased financial risks. In contrast, the constant regime proves to be more favourable for impatient households and entrepreneurs, offering stability and reduced risk exposure. Overall, while looser credit constraints provide short-term gains, long-term welfare and stability are better supported by tighter controls, in line with existing literature.

In summary, the study underscores the importance of adopting a dynamic macroprudential policy approach, where the CcLTV ratio can adjust to the evolving risks in different sectors of the economy. The findings demonstrate that while constant LTV ratios provide stability in certain contexts, the CcLTV regime is a more effective tool for addressing sector-specific risks, particularly in periods of financial distress.

8. Recommendations

The assessment explored the implementation approach of the CcLTV in Namibia. The study evaluates the impact of the current constant LTV ratio on financial stability and proposes the adoption of a CcLTV ratio as a macroprudential policy tool in Namibia. On this background, the following is recommended as a way forward:

1. **Borrower heterogeneity should be considered when implementing the CcLTV ratio.** To enhance the effectiveness of the macro-prudential policy, the policymakers (the Macroprudential Oversight Committee) should consider borrowers' heterogeneity and tailor the CcLTV regulation according to the specific conditions of each sector of the credit market, rather than to the aggregate credit market condition. In this way, the Macroprudential Oversight Committee can directly target the credit market sector, or the borrower type, where systemic risk is developing.

2. **Enhance the existing LTV ratio Determination and develop the CcLTV ratio framework.** This framework and the monitoring structure will enable the Macroprudential Oversight Committee to use the CcLTV regulation as its macroprudential tool by adjusting the LTV ratio to changes in credit and output in a countercyclical manner.

3. **Benchmark with international best practices:** Benchmark Namibia's CcLTV framework against international best practices and learn from other countries' experiences in putting CcLTV regulations into effect. This will help tailor and modify the policy to suit the country's unique financial landscape.

References

Almeida, H., Campello, M., & Liu, C. (2006). The financial accelerator: Evidence from international housing markets. *Review of Finance, 10*(3), 321–352.

Angelini, P., Neri, S., & Panetta, F. (2014). The interaction between capital requirements and monetary policy. Journal of money, credit and Banking, 46(6), 1073-1112.

Aoki, K., Proudman, J., & Vlieghe, G. (2004). House prices, consumption, and monetary policy: a financial accelerator approach. *Journal of financial intermediation*, *13*(4), 414-435.

Bank of Namibia. (2023). Guidance Note to Re-consider the Loan-To-Value Limits for Namibia.

Benes, J., Laxton, D., & Mongardini, J. (2018). Mitigating the deadly embrace in financial cycles: countercyclical buffers and loan-to-value limits. In *Global Economic Modeling: A Volume in Honor of Lawrence R. Klein* (pp. 90-111).

Bernanke, B. (2007). *The financial accelerator and the credit channel* (No. 296). Board of Governors of the Federal Reserve System (US).

Cerutti, M. E., Correa, M. R., Fiorentino, E., & Segalla, E. (2016). *Changes in prudential policy instruments—A new cross-country database*. International Monetary Fund.

Claessens, S., Ghosh, S. R., & Mihet, R. (2013). Macro-prudential policies to mitigate financial system vulnerabilities. *Journal of International Money and Finance*, *39*, 153-185.

Dell'Ariccia, G., Rabanal, P., Crowe, C. W., & Igan, D. O. (2011). Policies for macrofinancial stability: options to deal with real estate booms. *Staff Discussion Notes*, *2011*(002).

Duffy, D., McInerney, N., & McQuinn, K. (2016). Macroprudential policy in a recovering property market: too much too soon?. International Journal of Housing Policy, 16(4), 491-523.

IMF (2013): Key aspects of macroprudential policy, IMF Staff Paper, Washington DC: IMF

Gatt, W. (2023). Loan-to-value limits as a macroprudential policy tool: Developments in theory and practice. *Journal of Economic Surveys*.

Galati, G., & Moessner, R. (2013). Macroprudential policy—a literature review. *Journal of Economic Surveys*, 27(5), 846–878.

Jacome, L. I., & Mitra, S. (2015). LTV and DTI Limits-Going granular.

Jia, S. (2019). Supervision of and Response to China's Real Estate Bubble: The Effects of the Loan-to-Value Ratio Policy.

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

Lim, C. H., Costa, A., Columba, F., Kongsamut, P., Otani, A., Saiyid, M., ... & Wu, X. (2011). Macroprudential policy: what instruments and how to use them? Lessons from country experiences.

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

Liu, G., & Molise, T. (2019). Housing and credit market shocks: Exploring the role of rule-based Basel III counter-cyclical capital requirements. *Economic Modelling*, *82*, 264-279.

Liu, G., & Molise, T. (2021). The effectiveness of the counter-cyclical loan-to-value regulation: Generic versus sector-specific rules. *International Review of Economics & Finance*, *72*, 270-288.

O'Brien, E., & Ryan, E. (2017). *Motivating the Use of Different Macro-prudential Instruments: The Countercyclical Capital Buffer vs. Borrower-Based Measures* (No. 15/EL/17). Central Bank of Ireland.

Robinson, T., & Yao, F. (2016, March). Consequences of Loan-to-Value Ratio Policies for Business and Credit Cycles. In *Australian Conference of Economists*.

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

Tobin, J. (1969). A general equilibrium approach to monetary theory. *Journal of money, credit and banking*, *1*(1), 15-29.

Wong, T. C., Fong, T., Li, K. F., & Choi, H. (2011). Loan-to-value ratio as a macroprudential tool-Hong Kong's experience and cross-country evidence. *Systemic Risk, Basel III, Financial Stability and Regulation*.

Zhang, L., & Zoli, E. (2016). Leaning against the wind: Macroprudential policy in Asia. *Journal of Asian Economics*, *42*, 33-52.

Zidonyte, M. (2015). *Loan to value ratios and housing prices. Evidence from Central and Eastern Europe* (master's thesis).

Appendix

Appendix A

Table 4 : LTV regulation: Country experiences.

Country	Year	Motivation	Action
Bulgaria	2004-2007	A credit boom was accompanied by a house price boom in the early 2000s. In 2004, rapid growth of 49 percent in bank lending led to concerns about banks' ability to manage the credit and operational risk associated with such rapid credit growth. The authorities introduced measures to limit the build-up of risk for the banking sector cut lending growth and minimise systemic risk.	Introduction of a 70 percent LTV ratio for mortgages, risk-weighted at 50 percent.
Canada	2008-2011	Experienced rapid mortgage growth in 2008 and high household debt in 2010 and 2011. Under these circumstances, the Ministry of Finance introduced several policy measures to protect and strengthen the Canadian housing market and support its long-term stability.	Introduced LTV in July 2008, the maximum term for mortgages was decreased from 40 to 35 years. In February 2010, the government selectively tightened the LTV ceilings on cash-out refinancing transactions and investment property loans. In April 2011, the maximum amortization period for new government-backed insured mortgages with LTV ratios of more than 80% was reduced to 30 years from 35 years.
Chile	2008-2009	Economic activity declined as a fall-out from the GFC. In response, the authorities enacted measures to restore the flow of credit, especially to low-income households and small and medium-sized enterprises.	Raised the maximum LTV ratio for bond-type mortgages from 75 percent to 100 percent for debtors with higher credit ratings in 2009.
China	2010-2011	The authorities implemented a massive stimulus package in 2008 to counter the effects of the financial crisis. The stimulus worked quickly to stem the contraction in output, but it was not withdrawn immediately. The delay in the policy exit helped fuel a domestic credit boom. From late-2009, housing prices began to rise at an average annual rate of 15-20 percent. The authorities introduced several measures to curb credit growth and housing price inflation.	The LTV ratio on primary homes was lowered from 80 percent to 70 percent and to 50 percent on second homes in 2010. The LTV ratio on purchases of second homes was subsequently lowered further to 40 percent in 2011.
Colombia	Late 1990s	Colombia experienced excessive leverage from mortgage borrowers and suffered a mortgage crisis. Based on such experience, the authorities introduced several measures to limit the exposure of households to debt reduce excessive leverage from mortgage borrowers.	Introduction of caps on LTV ratios at 70 percent in 1999.

Croatia	2003-2008	The authorities took action to slow down the rapid credit growth, reduce procyclicality, slow down foreign borrowing and encourage banks to apply prudent business, policies in their foreign borrowing.	Introduction of LTV ratio for housing loans at 75 percent in 2006.
Hong Kong	1990s	Real estate prices started inflating in the late 1980s and accelerated in 1993. Mortgage loans as a percentage of GDP also grew rapidly. The authorities acted to moderate mortgage growth and property price inflation.	Reduction in LTV ratio from 80-90 percent to 70 percent in 1991, and a further reduction of the LTV ratio to 60 percent for luxury residences in 1997.
India	2004-2010	Up until the global financial crisis, strong economic growth and urbanisation started a real estate boom and credit to the private sector, including loans to households for housing and consumer credit. After the global crisis, credit started to decline, and the authorities' main objective was to reduce procyclicality.	Introduction of 80 percent of LTVs for residential real estate (2010).
Italy	2007	Italian bank lending accelerated owing to strong corporate demand for funds fuelled by the recovery in activity; bank lending to households continued to grow fast. The proportion of loans associated directly or indirectly with real estate activity increased further. Motivation to act was to reduce lending cyclicality.	Introduction of caps on LTV in 2007. Mortgages secured by residential real estate are discouraged when they are beyond 80 percent loan to value. Tighter capital requirements are requested for loans above 80 percent loan to value.
Korea	2002-2011	The Korean banking system was vulnerable to housing market booms. In the aftermath of the Asian crisis, expansive policies to stimulate the economy created a credit boom (in particular, credit cards), the bust of which came in 2003 and left policymakers with a desire for tougher regulation. Real house prices increased during 2001Q1 to 2003Q3 after stalling in 2004, price appreciation resumed in 2005 and recorded an increase between 2005Q1 and 2007Q1. But prices declined again due to the negative effect of the global financial crisis. Given the systemic impact of housing policies, both on consumer confidence and overall macroeconomic management, as well as the social welfare purposes, the Korean authorities tightly regulate the housing market.	Introduction of caps on LTV ratios in 2002. Since then, tightened 4 times and loosened once in accordance with property price fluctuations. -DTI: introduction of caps on debt-to-loan ratio in 2005. Since then, tightened 4 times and loosened 2 times in accordance with property price fluctuations.
Norway	2010	Household debt (mainly mortgages) reached a high level and was a key risk in Norway. The drivers behind the build-up of risk in the banking sector were a combination of demand and supply factors. On the demand side, low unemployment, and wealth effects from increases in oil prices helped to boost the accumulation of household debt. On the	LTV: 90 percent cap on LTV for housing loans and 75 percent cap on LTV for home equity loans.

		supply of credit side, lax lending standards and aggressive mortgage lending practices also played a role. The main motivations to act were to address the problems of high housing debt.	
Singapore	2009-2011	Real estate cycles have been strong with an increase of 45 percent in real house prices from 2004Q2 to 2008Q1. During the global financial crisis, the private property price index declined almost 25 percent between its peak in 2008Q2 and its trough in 2009Q2, but it rebounded sharply since 2009Q3. Since 2009, there has been a risk of excessive house prices, including potential bubbles, and risks of increasing speculative demand. The main motivations to apply measures during the recovery after the global financial crisis were to: ensure a stable and sustainable property market reduce further speculative demand	LTV: reduction of caps on LTV from 90 percent to 80 percent for all borrowers (2010) This was lowered to 70 percent for borrowers who have one or more outstanding housing loans at the point of applying for the new housing loan (later in 2010) and reduced further to 60 percent for borrowers who have one or more outstanding housing loans and to 50 percent for non-individuals (2011).
Sweden	2010	There was a sign of excessive indebtedness, which would make borrowers vulnerable to a situation in which real estate prices decline. The motivations were to: Stem an unsound trend in the credit market and protect consumers.	LTV cap of 85 percent for mortgages.
Turkey	2009-2010	Turkey rebounded rapidly after the global financial crisis. The country saw a rapid increase in domestic demand, rapid credit growth, and increased foreign currency borrowing by banks. The motivations to take actions were to slow credit growth and improve credit quality.	Introduction of caps on the LTV ratio for real estate loans.

Table 5: LTV ratios, 2016.

Categorization of mortgage loan	Percentage points of LTV
First non-primary residence	80 percent
Second non-primary residence	70 percent
Third non-primary residence	60 percent
Fourth and all subsequent non-primary residences	50 percent

Source: Banking Institutions Act 2 of 1988, Regulations relating to Restrictions on Loan-to-Value Ratios, (2016)

Table 6: LTV ratios, 2019

Categorisation of mortgage loan	LTV ratios
First residential property	Not applicable
Second residential property	90 percent
Third and subsequent residential properties	80 percent

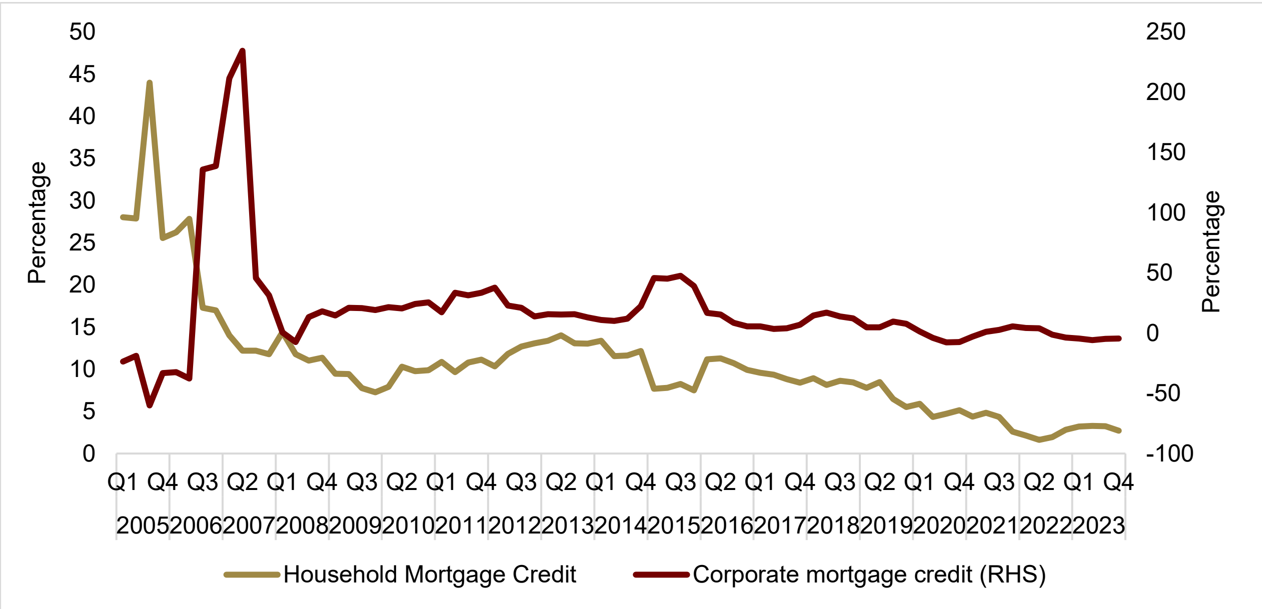
Source: Banking Institutions Act 2 of 1988, Regulations relating to Restrictions on Loan-to-Value Ratios, (2019)

Table 7: LTV ratios, 2023

Categorization of mortgage loan	LTV ratios
First residential property	Not applicable
Second residential property	Not applicable
Third and subsequent residential properties	90 percent

Source: Banking Institutions Act 2 of 1988, Regulations relating to Restrictions on Loan-to-Value Ratios, (2023)

Figure 3: Corporate and household mortgage credit growth



Source: BoN

Appendix B: Complete set of equations for the model

The model economy consists of a complete set of non-linear equations for 28 endogenous variables and 3 stochastic shocks.

Endogenous variables in the model

$C_{s,t}$ - Patient household consumption

$R_{d,t}$ - Real gross return on a one-period risk-free deposit

q_t - Relative price of housing

$H_{s,t}$ - Housing stock for patient households

$W_{s,t}$ - Real wage rate for patient households

$C_{b,t}$ - Impatient household consumption

$L_{b,t}$ - Impatient household's loan

$R_{b,t}$ - Real gross interest rate for impatient households

$H_{b,t}$ - Housing stock for impatient households

$W_{b,t}$ - Real wage rate for impatient households

$C_{e,t}$ - Entrepreneurs consumption

Y_t - Production

$L_{e,t}$ - Entrepreneurs loan

$H_{e,t}$ - Housing stock for impatient households

$R_{e,t}$ - Real gross interest rate for entrepreneurs

$C_{f,t}$ - Dividend payments from the bank

D_t - Household's deposits

m_b – Impatient household's LTV rule

m_e - Entrepreneurs LTV rule

$AC_{bf,t}$ - Loan portfolio adjustment costs associated with household loans

$AC_{ef,t}$ - Loan portfolio adjustment costs associated with entrepreneur loans

$\lambda_{b,t}$ – Multiplier on the impatient households borrowing constraint

$\lambda_{f,t}$ - Multiplier on the bank's borrowing constraint

$\lambda_{e,t}$ - Multiplier on the entrepreneur's borrowing constraint

C_t - Aggregate consumption

L_t - Aggregate loans

Exogenous variables

A_t- Housing demand shock

$\varsigma_{b,t}$ – Loan loss shock for impatient household

$\varsigma_{e,t}$ - Loan repayment shock for entrepreneur

Z_t – Technology shock

Parameters

β_s – Discount factor (patient household (HH)

β_b – Discount factor (impatient HH)

β_e - Discount factor (entrepreneur)

β_f - Discount factor (bank)

τ - Labor supply parameter

σ- Impatient HH's income share

η_i - Habit persistence, $i = b, s, e. f$

$\emptyset_{b,f}$ - Loan to HH adj. cost, bank

$\emptyset_{e,f}$ - Loan to Entrep. adj. cost, Bank

v - Housing share in production

j - Housing preference

k - Steady state capital requirement ratio

ρ_z - Autocorrelation technology shock

ρ_a – Autocorrelation housing demand shock

$\rho_{\varsigma i}$ - Autocorrelation financial (loan loss) $i = \{b, e\}$

w_b - Risk weight (Impatient HH's loan)

w_e- Risk weights (Entrep. loan)

m_b – Impatient household's LTV rule

m_e - Entrepreneurs LTV rule

The system of equations

Patient Households

$C_{s,t}$+$D_{,t}$+ $q_t(H_{s,t}$-$H_{s,t-1})$= $W_{s,t}N_{s,t}$+$R_{d,t-1}D_{t-1}$, B.1

1 = $\beta_s\, E_t(\frac{U_{Cs,t+1}}{U_{Cs,t}} R_{d,t})$, B.2

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

$W_{s,t}$, = $\frac{\tau}{(1- N_{s,t})U_{Cs,t}}$, B.4

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

Impatient Households

$C_{b,t}$ + $R_{b,t-1}L_{b,t-1}$ + $q_t(H_{b,t}$-$H_{b,t-1})$ = $W_{b,t}N_{b,t}$ + $L_{b,t}$ + $\varsigma_{b,t}$, B.5

$L_{b,t}$ = $m_{b,t}E_t(\frac{q_{t+1}}{R_{b,t}}H_{b,t})$, B.6

1 = $\beta_b\, E_t(\frac{U_{Cb,t+1}}{U_{Cb,t}} R_{b,t})$ + $\frac{\lambda_{b,t}}{U_{Cb,t}}$, B.7

q_t = j$\frac{A_t}{H_{b,t}U_{cb,t}}$ + $\beta_b\, E_t(\frac{U_{Cb,t+1}}{U_{Cb,t}}\, q_{t+1})$ + $m_{b,t}$ ($\frac{\lambda_{b,t}}{U_{Cb,t}}$) E_t($\frac{q_{t+1}}{R_{b,t}}$), B.8

$W_{b,t}$, = $\frac{\tau}{(1- N_{b,t})U_{Cb,t}}$, B.9

where $U_{Cb,t}$ $\frac{1-\eta_b}{C_{b,t}-\eta_b C_{b,t-1}}$.

Entrepreneurs

$C_{e,t}$ + $q_t(H_{e,t}$- $H_{e,t-1})$ + $R_{e,t}L_{e,t-1}$ + $W_{s,t}N_{s,t}$ + $W_{b,t}N_{b,t}$ = Y_t + $L_{e,t}$+ $\varsigma_{e,t}$, B.10

Y_t =$Z_t H^{v}_{e,t-1}[N^{1-\sigma}_{s,t} N^{\sigma}_{b,t}]^{1-v}$, B.11

$L_{e,t}$ = $m_{e,t}E_t(\frac{q_{t+1}}{R_{e,t}} H_{e,t})$, B.12

q_t = β_e $E_t(\frac{U_{Ce,t+1}}{U_{Ce,t}})(v\frac{Y_{t+1}}{H_{e,t}} q_{t+1})$ + $m_{e,t}$ ($\frac{\lambda_{e,t}}{U_{Ce,t}}$) E_t $\frac{q_{t+1}}{R_{e,t+1}}$, B.13

$W_{s,t}, N_{s,t}$, = $(1- \sigma)(1-v)$ Y_t, B.14

$W_{b,t}, N_{b,t}$, = $\sigma(1-v)$ Y_t , B.15

1 = $\frac{\lambda_{e,t}}{U_{Ce,t}}$ + β_e $E_t\frac{U_{Ce,t+1}}{U_{Ce,t}} R_{e,t+1}$, B.16

where $U_{Ce,t}$ $\frac{1-\eta_e}{C_{e,t}-\eta_e C_{e,t-1}}$.

The Bank

$C_{f,t} + R_{d,t-1}D_{t-1}$+$L_{b,t} + L_{e,t} + AC_{bf,t}$+$AC_{ef,t} = D_t + R_{b,t-1}L_{b,t-1}$+$R_{e,t}L_{e,t-1}$- ψ_t, B.17

D_t = (1 - w_ek) $\left(L_{e,t} - E_t\psi_{e,t+1}\right)$+ *(1 -* w_b*k)* $\left(L_{b,t} - E_t\psi_{b,t+1}\right)$, B.18

$\beta_f E_t\frac{U_{Cf,t+1}}{U_{Cf,t}} R_{d,t}$ = 1 - $\frac{\lambda_{f,t}}{U_{Cf,t}}$, B.19

$\beta_f E_t\frac{U_{Cf,t+1}}{U_{Cf,t}} R_{b,t}$ = *1 – (1-* w_b*k) (* $\frac{\lambda_{f,t}}{U_{Cf,t}}$ *)* + $\frac{\emptyset_{b,f}}{L_b}$ ($L_{b,t} - L_{b,t-1}$)$\mathrm{R}_{\mathrm{b,t}}$, B.20

$\beta_f E_t\frac{U_{Cf,t+1}}{U_{Cf,t}} R_{e,t+1}$ = *1 – (1-*w_e*k) (* $\frac{\lambda_{f,t}}{U_{Cf,t}}$ *)* + $\frac{\emptyset_{e,f}}{L_e}$ ($L_{e,t} - L_{e,t-1}$), B.21

$AC_{bf,t} = \frac{\emptyset_{bf}}{2}\frac{(L_{b,t}-L_{b,t-1})^2}{L_b}$, B.22

$AC_{ef,t} = \frac{\emptyset_{ef}}{2}\frac{(L_{e,t}-L_{e,t-1})^2}{L_e}$, B.23

where $U_{Cf,t} = \frac{1-\eta_f}{C_{f,t}-\eta_f C_{f,,t-1}}$.

Macroprudential Authority

$$m_{b,t} = m_b \left(\frac{L_{b,t}}{L}\right)^{-X_{l,m_b}} \left(\frac{Y_t}{Y}\right)^{-X_{y,m_b}}, \qquad \text{B.24}$$

$$m_{e,t} = m_e \left(\frac{L_{e,t}}{L}\right)^{-X_{l,m_e}} \left(\frac{Y_t}{Y}\right)^{-X_{y,m_e}}, \qquad \text{B.25}$$

Market equilibrium conditions

$$C_t = C_{s,t} + C_{b,t} + C_{e,t} + C_{f,t}, \qquad \text{B.26}$$

$$H_{s,t} + H_{b,t} + H_{e,t} = 1, \qquad \text{B.27}$$

$$L_t = L_{b,t} + L_{e,t}, \qquad \text{B.28}$$

$$N_{s,t} + N_{b,t} = 1, \qquad \text{B.29}$$

Shock processes

$$log(A_t) = p_a log((A_{t-1}) + \xi_{a,t}$$

$$\varsigma_{b,t} = \rho_\varsigma \varsigma_{b,t-1} + \xi_{\varsigma,t}$$

$$\varsigma_{e,t} = \rho_\varsigma \varsigma_{e,t-1} + \xi_{\varsigma,t}$$

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

Steady-state equations

$$C_s = W_s N_s + (R_d - 1)D \qquad \text{B.1}$$

$$R_d = \frac{1}{\beta_s} \qquad \text{B.2}$$

$$q = \frac{JC_s}{H_s} \frac{1}{(1-\beta_s)} \qquad \text{B.3}$$

$$W_s = \frac{\tau\, C_s}{(1-N_s)} \qquad \text{B.4}$$

$$C_b = W_b N_b + (1 - R_d\ ) L_b \qquad \text{B.5}$$

$$L_b = m_b \left(\frac{q}{R_b} H_b\right) \qquad \text{B.6}$$

$$\lambda_b = \frac{(1-\beta_b R_b)}{C_b}$$ B.7

$$H_b = \frac{JC_b}{q\left(1-\beta_b - \frac{m_b(\lambda_b C_b)}{R_b}\right)}$$ B.8

$$W_b = \frac{\tau C_b}{(1-N_b)}$$ B.9

$$C_e = Y + (1 - R_e) L_e - W_s N_s - W_b N_b$$ B.10

$$Y = H_e^{v}(N_s^{1-\sigma} N_b^{\sigma})^{1-v}$$ B.11

$$L_e = m_e \left(\frac{q}{R_e} H_e\right)$$ B.12

$$H_e = \frac{\beta_e vY}{q\left(1-\beta_e - \frac{m_e(\lambda_e C_e)}{R_e}\right)}$$ B.13

$$N_s = \frac{(1-\sigma)(1-v)Y}{W_s}$$ B.14

$$N_b = \frac{\sigma(1-v)Y}{W_b}$$ B.15

$$\lambda_e = \frac{(1-\beta_e R_e)}{C_e}$$ B.16

$$C_f = (1 - R_d)\mathrm{D} + (R_b - 1)L_b + (R_e - 1)L_e$$ B.17

$$D = (1 - W_{ek})L_e + (1 - W_{bk})L_b$$ B.18

$$\lambda_f = \frac{(1-\beta_f R_d)}{C_f}$$ B.19

$$R_b = \frac{w_{bk}}{\beta_f} + \frac{(1-w_{bk})}{\beta_s}$$ B.20

$$R_e = \frac{w_{ek}}{\beta_f} + \frac{(1-w_{ek})}{\beta_s}$$ B.21

Market Equilibrium Steady-state equations

$$C = C_s + C_b + C_e + C_f$$ B.22

$$H_s + H_b + H_e = 1$$ B.23

$$L = L_b + L_e$$ B.24

$$N_s + N_b = 1$$ B.25