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The Conduct of LTV Policy under Inflationary Shocks

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Abstract

This paper examines loan-to-value (LTV) policy as a macroprudential tool and its interactions with monetary policy in an inflationary environment. The combination of inflation shocks and collateral constraints introduces additional trade-offs for policymakers, emphasizing the need for coordination between macroprudential and monetary policies. Using a DSGE model with collateral constraints, we evaluate the implications of an optimized LTV rule for a welfare-based loss function that incorporates economic and financial stability. Our core finding indicates that, under inflation shocks, policy coordination reduces welfare-based losses compared to a non-coordination regime. In particular, the LTV rule is active (responding to cyclical factors, e.g. house prices) when monetary policy responds weakly to inflation shocks, but the LTV rule becomes passive (only responding to structural factors) when monetary policy chooses to be hawkish towards inflation.

JEL classification: E32, E44, E58.

Keywords: LTV policy, Monetary Policy, macroprudential policy coordination, collateral constraints, financial friction, cost-push shocks.

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1 Non-technical summary

This paper investigates how loan-to-value (LTV) ratio policies—a key macroprudential tool—interact with monetary policy in an inflationary environment. Inflation shocks introduce unique challenges for policymakers, creating trade-offs between managing inflation and ensuring financial stability. The simultaneous use of hawkish monetary policy to combat inflation and restrictive LTV policies to stabilize financial markets can amplify negative effects on economic growth. This raises important questions about the coordination of these two policy instruments.

Using a state-of-art macroeconomic model, we explore how optimized LTV rules can complement monetary policy in addressing inflation shocks. The model demonstrates that inflationary shocks interacting with financial frictions create new trade-offs for policy makers: while monetary policy faces the conventional trade-off between volatility of inflation and output, LTV policy must address disparities between borrowers and savers. These disparities, representing financial stability risks, become more pronounced when inflationary pressures necessitate higher interest rates.

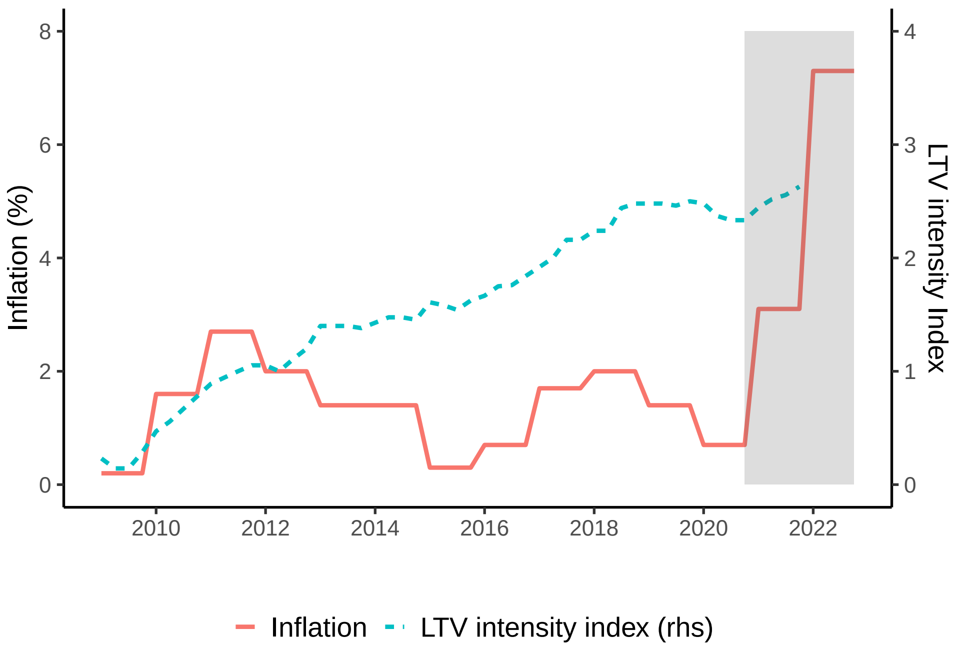
Our results suggest that coordinated policy approaches yield better outcomes than non-coordinated strategies. In a non-coordination scenario, where LTV policy reacts independently to housing market conditions, higher interest rates not only increase borrowing costs but also tighten credit conditions, leading to more welfare losses for credit constraint borrowers. Conversely, under a coordination regime, LTV policies adjust in response to monetary policy, softening the impact on borrowers. This approach balances price stability with financial stability, improving overall economic welfare.

In essence, this paper highlights the importance of policy coordination in achieving macroeconomic and financial stability in challenging inflationary conditions. By illustrating the complementary roles of monetary and macroprudential policies, it provides insights for central banks navigating today's inflationary landscape.

2 Introduction

The inflationary environment poses a unique challenge to the notion of "complementarity" between macro-financial stabilization policies. Under the conventional view, managing inflation and safeguarding financial stability are regarded as distinct policies with different objectives and instruments (see, e.g., Svensson, 2012). However, persistent inflationary shocks have triggered intense and prolonged monetary policy tightening, further heightening concerns about growth and borrowers' resilience. In this environment, if macroprudential policy begins to address financial stability concerns, it might further amplify the negative effects of inflationary shocks on economic growth. In other words, inflationary shocks have created a more challenging setting for the interaction between macroprudential and monetary policies.

Figure 1. Average LTV policy intensity index and inflation rates



Data source: IMF integrated Macroprudential Policy (iMaPP) Database and World Economic Outlook (Oct. 2024).
Notes: The dotted line is based on the cumulative sum of average policy index of the LTV instrument over 36 advanced economies. The red solid line represents the average inflation rate, defined as the annual percent change of average consumer prices across 36 advanced economies.

Since the 2008 Global Financial Crisis (GFC), macroprudential policies have been at the forefront of economic policymaking to address the risks of financial instability. According to Alam et al. (2019), the loan-to-value ratio (LTV) is the most widely used macroprudential instrument in advanced economies.[1] This policy serves as a first

[1] As of December 2016, 23 out of 36 advanced economies (AEs) had used the LTV instrument, making it the most frequently adjusted macroprudential tool. Among AEs, the number of policy actions was highest for LTV limits, averaging 0.17 adjustments per year between 2010 and 2016.

line of defense against excessive credit growth and contributes to both financial and macroeconomic stability (see Rubio and Carrasco-Gallego, 2014). As shown in Figure 1, LTV policies tightened across advanced economies following the GFC but briefly reversed course during the COVID-19 pandemic. However, since inflation began to rise in 2021, LTV policies in advanced economies have resumed their tightening trajectory, coinciding with monetary policy responses to high inflation. In this inflationary context, the debate about coordinating monetary and macroprudential policies has gained renewed importance. This paper revisits the 'Tinbergen' perspective on policy coordination under inflationary conditions.

To address this complex policy issue, we employ a standard DSGE model with collateral constraints based on Iacoviello (2005). Iacoviello-type models are New Keynesian DSGE frameworks with housing and collateral constraints, providing a microfoundation for implementing LTV policy. We incorporate a Taylor-type rule for the LTV and use a welfare-based loss function to study optimal simple rules for LTV policy in response to inflationary shocks. In this model, under cost-push shocks,[2] the collateral constraint introduces additional trade-offs between macroeconomic and financial stability, alongside the traditional trade-off between inflation and real economic activity. As is well understood, the inflation/output trade-off becomes especially acute during cost-push (supply-side) shocks, as monetary policy cannot simultaneously stabilize both variables. This creates a downward-sloping policy frontier between their variabilities, known as the Taylor curve. Our model demonstrates that, when collateral constraints are included in the inflationary environment, a cost-push shock exacerbates the inflation/output trade-off. However, loosening collateral constraints can shift the Taylor curve leftward, improving this trade-off. At the same time, collateral constraints introduce a new trade-off between price stability and the housing/consumption gap between borrowers and savers, representing the "stand-in" financial stability risk in the model.[3] Under inflationary shocks and collateral constraints, these more complex trade-offs call for enhanced coordination between LTV and monetary policy.

In the final section, we conduct an optimal simple rule analysis to explore LTV policy under a pre-set monetary policy targeting inflation in response to cost-push shocks. We analyze the optimal simple rule coefficients for the LTV policy given a fixed monetary policy stance. In this setting, we assume that LTV policy reacts countercyclically to house price fluctuations while treating monetary policy as exogenous. Our findings indicate that, under the "Non-coordination regime," LTV policy operates independently of monetary policy. Regardless of monetary policy's stance, LTV policy responds strongly to house price changes. As predicted by the traditional supply-shock trade-off, a stronger monetary policy response to inflation reduces inflation volatility but increases output volatility. Additionally, heightened monetary tightening exacerbates financial stability concerns in the model economy, reflected in the widening consumption and housing gaps between savers and borrowers. Borrowers face not only higher interest rates on debt but also stricter borrowing conditions under tighter LTV limits, further hindering their ability to smooth consumption and purchase housing during inflationary

[2] Cost-push shocks are a standard mechanism for generating inflation in DSGE models. This approach does not imply that the current inflationary period is solely caused by cost-push shocks.

[3] In a DSGE model without bank credit defaults, financial stability risks are represented by the widening inequality between savers and borrowers in terms of consumption and housing services.

shocks. As a result, the volatility of the housing gap and welfare-based losses rise sharply under the non-coordination regime. In contrast, under the "Coordination regime," LTV policy accounts for monetary policy's stance. In particular, the LTV rule is active (responding to cyclical factors, e.g. house prices) when monetary policy responds weakly to inflation shocks, but the LTV rule becomes passive (only responding to structural factors) when monetary policy chooses to be hawkish towards inflation. The rule softens its stance on house prices when monetary policy aggressively targets inflation. This approach balances price stability and financial stability concerns, resulting in an overall improvement in welfare-based losses compared to the non-coordination regime.

The rest of the paper is structured as follows: Section 2 reviews the related literature. Section 3 outlines the model. Section 4 discusses policy trade-offs. Section 5 presents the optimized LTV policy, and Section 6 concludes.

3 Related Literature

With inflation shocks at the center of our research question, this paper also connects to the classic literature examining monetary policy trade-offs between output and inflation volatility. A substantial body of work explores the nature of this trade-off in theoretical models (e.g., Rudebusch and Svensson, 1997; Fuhrer, 1997; McCallum and Nelson, 1998; Clarida, Gali, and Gertler, 1999; Erceg, Henderson, and Levin, 2000; King and Wolman, 1999; and Woodford, 1999). Most of these studies highlight the necessity of accepting some inflation variability to achieve greater stability in real output. More recently, an intense debate has emerged about whether monetary policy should also consider financial stability (see, e.g., Rudebusch, 2006, and Dell'Ariccia et al., 2014).

Similar to our approach, Iacoviello (2005) conducts a Taylor curve analysis to evaluate whether monetary policy should respond to house prices. He finds that loosening collateral constraints shifts the Taylor curve inward slightly. Along similar lines, Rubio (2016) examines the effectiveness of monetary policy under fixed and variable-rate contracts using a Taylor curve framework. This study concludes that the effectiveness of macroprudential policies depends on the degree of sluggishness in interest rate pass-through, as their interaction with monetary policy influences financial stability. Rubio and Carrasco-Gallego (2014), using a model with collateral constraints, propose a three-dimensional Taylor curve that incorporates credit variability as an additional dimension. However, they do not derive an analytical welfare function.

In contrast, we utilize an analytical welfare-based loss function directly derived from the Iacoviello (2005) model (see Rubio and Yao, 2020). This function identifies the additional terms that optimal policy should account for, encompassing not only inflation and output volatility but also the housing and consumption gaps between borrowers and savers. These gap terms represent the financial stability dimension of the model with collateral constraints, capturing the real-world financial stability concern as reflected by the widening inequality between savers and borrowers in terms of consumption and housing services. We show that these differing—and often conflicting—dimensions of welfare losses from the model complicate the implementation of an optimal monetary policy rule, reinforcing the argument for employing macroprudential policies as a complement to monetary policy to achieve optimal outcomes.

Building on this discussion, our paper is also closely aligned with the literature on optimal LTV rules and their interaction with monetary policy rules. Rubio and Carrasco-

Gallego (2014) and Lambertini et al. (2013) analyze this interaction, while Angelini et al. (2012) consider optimal monetary and macroprudential policy rules using both the LTV and capital requirements as instruments. Rubio and Yao (2020) focus on the interplay between LTV and monetary policy at the Zero Lower Bound (ZLB), finding that macroprudential policy is the appropriate tool to complement monetary policy at the ZLB for achieving macroeconomic and financial stability. Similarly, Garcia-Revelo and Lieveuge (2022) show that conflicts between macroprudential and monetary policies, while not systematic, are particularly likely during investment efficiency and bank capital shocks. In a more recent contribution, Ferrero et al. (2024) study the optimal design of LTV policy and its implications for monetary policy, incorporating an effective lower bound on nominal interest rates and an upper bound on the LTV ratio. They find that optimal LTV limits are strongly countercyclical. Our paper adds to this literature by focusing on the implications of LTV policy in an inflationary environment, a context that is highly relevant to current policy debates.

The Central Bank of Ireland has implemented borrower-based measures, including LTV and loan-to-income (LTI) limits, since 2015. A robust research agenda has since emerged to evaluate the effects of these instruments. For example, Kelly, McCann, and O'Toole (2018) analyze the impact of borrower-based measures on house prices, while McCann and Ryan (2016) demonstrate that lower LTV ratios at origination enhance the resilience of banks' mortgage portfolios during adverse events. Arigoni, McCann, and Yao (2022) assess the effects of recalibrating borrower-based measures on the aggregate house price-to-income ratio. Clancy and Merola (2017) show that time-varying capital buffers effectively shield the economy from systemic risks. However, their DSGE model abstracts from the collateral channel, which is a key focus of our paper. Our findings similarly support the countercyclical use of LTV policy.

4 Model Setup

The economy features patient and impatient households, a final goods firm, a central bank which conducts monetary policy, and a macroprudential authority that sets financial regulation. Households work and consume both consumption goods and housing. Patient and impatient households are savers and borrowers, respectively. Borrowers are credit constrained and need collateral to obtain loans. The representative firm converts household labor into the final good. The central bank follows a Taylor rule for the setting of interest rates and the macroprudential regulator uses the LTV as an instrument for macroprudential policy.

4.1 Savers

Savers maximize their utility function by choosing consumption, housing and labor hours:

$$\max_{C_{s,t},H_{s,t},N_{s,t}} E_0 \sum_{t=0}^{\infty} \beta_s^t \left[\log C_{s,t} + j \log H_{s,t} - \frac{(N_{s,t})^\eta}{\eta} \right],$$

where $\beta_s \in (0,1)$ is the patient discount factor, E_0 is the expectation operator and $C_{s,t}$, $H_{s,t}$ and $N_{s,t}$ represent consumption at time t, the housing stock and working hours, respectively. $1/(\eta-1)$ is the labor supply elasticity, $\eta>0$. j represents the weight of housing in the utility function.

Subject to the budget constraint:

$$C_{s,t}+b_t+q_t\left(H_{s,t}-H_{s,t-1}\right)=\frac{R_{t-1}b_{t-1}}{\pi_t}+w_{s,t}N_{s,t}+F_t, \tag{1}$$

where b_t denotes bank deposits, R_t is the gross return from deposits, q_t is the price of housing in units of consumption, and $w_{s,t}$ is the real wage rate. F_t are lump-sum profits received from the firms. The first order conditions for this optimization problem are as follows:

$$\frac{1}{C_{s,t}}=\beta_s E_t\left(\frac{R_t}{\pi_{t+1}C_{s,t+1}}\right), \tag{2}$$

$$w_t^s=\left(N_{s,t}\right)^{\eta-1}C_{s,t}, \tag{3}$$

$$\frac{j}{H_{s,t}}=\frac{1}{C_{s,t}}q_t-\beta_s E_t\frac{1}{C_{s,t+1}}q_{t+1}. \tag{4}$$

Equation (2) is the Euler equation, the intertemporal condition for consumption. Equation (4) represents the intertemporal condition for housing, in which, at the margin, benefits for consuming housing equate costs in terms of consumption. Equation (3) is the labor-supply condition.

4.2 Borrowers

Borrowers solve:

$$\max_{C_{b,t},H_{b,t},N_{b,t}} E_0\sum_{t=0}^{\infty}\beta_b^t\left[\log C_{b,t}+j\log H_{b,t}-\frac{\left(N_{b,t}\right)^{\eta}}{\eta}\right],$$

where $\beta_b\in(0,1)$ is impatient discount factor, subject to the budget constraint and the collateral constraint:

$$C_{b,t}+\frac{R_{t-1}b_{t-1}}{\pi_t}+q_t\left(H_{b,t}-H_{b,t-1}\right)=b_t+W_{b,t}N_{b,t}, \tag{5}$$

$$E_t\frac{R_t}{\pi_{t+1}}b_t=k_t E_t q_{t+1}H_{b,t}, \tag{6}$$

where b_t denotes bank loans and R_t is the gross interest rate. k_t can be interpreted as a loan-to-value ratio.[4] The borrowing constraint limits borrowing to the present discounted value of their housing holdings. The first order conditions are as follows:

$$\frac{1}{C_{b,t}}=\beta_b E_t\left(\frac{R_t}{\pi_{t+1}C_{b,t+1}}\right)+\lambda_t R_t, \tag{7}$$

$$w_{b,t}=\left(N_{b,t}\right)^{\eta-1}C_{b,t}, \tag{8}$$

[4]In standard housing models, the LTV is a parameter. However, in our model, this has a subindex t because it is the macroprudential instrument.

$$\frac{j}{H_{b,t}} = \frac{1}{C_{b,t}} q_t - \beta_b E_t \left(\frac{1}{C_{b,t+1}} q_{t+1} \right) - \lambda_t k_t E_t \left(q_{t+1} \pi_{t+1} \right). \tag{9}$$

where λ_t denotes the multiplier on the borrowing constraint.[5] These first order conditions can be interpreted analogously to the ones of savers.

4.3 Firms

4.3.1 Final Goods Producers

There is a continuum of identical final goods producers that operate under perfect competition and flexible prices. They aggregate intermediate goods according to the production function

$$Y_t = \left[\int_0^1 Y_t \left(z \right)^{\frac{\varepsilon - 1}{\varepsilon}} dz \right]^{\frac{\varepsilon}{\varepsilon - 1}}, \tag{10}$$

where $\varepsilon > 1$ is the elasticity of substitution between intermediate goods. The final good firm chooses $Y_t \left(z \right)$ to minimize its costs, resulting in demand of intermediate good z:

$$Y_t \left(z \right) = \left(\frac{P_t(z)}{P_t} \right)^{-\varepsilon} Y_t. \tag{11}$$

The price index is then given by:

$$P_t = \left[\int_0^1 P_t \left(z \right)^{1-\varepsilon} dz \right]^{\frac{1}{\varepsilon - 1}}. \tag{12}$$

4.3.2 Intermediate Goods Producers

The intermediate goods market is monopolistically competitive. Following Iacoviello (2005), intermediate goods are produced according to the production function:

$$Y_t \left(z \right) = A_t N_{s,t} \left(z \right)^{\alpha} N_{b,t} \left(z \right)^{(1-\alpha)}, \tag{13}$$

where $\alpha \in [0, 1]$ measures the relative size of each group in terms of labor.[6] This Cobb-Douglas production function implies that labor efforts of constrained and unconstrained consumers are not perfect substitutes. This specification is analytically tractable and allows for closed form solutions for the steady state of the model. This assumption can be economically justified by the fact that savers are the managers of the firms and their wage is higher than the one of the borrowers.[7]

A_t represents technology and it follows the following autoregressive process:

$$\log \left(A_t \right) = \rho_A \log \left(A_{t-1} \right) + u_{At}, \tag{14}$$

[5] Through simple algebra it can be shown that the Lagrange multiplier is positive in the steady state and thus the collateral constraint holds with equality.

[6] Notice that the absolute size of each group is one.

[7] It could also be interpreted as the savers being older than the borrowers, therefore more experienced.

where ρ_A is the autoregressive coefficient and u_{At} is a normally distributed shock to technology. We normalize the steady-state value of technology to 1.

Labor demand is determined by:

$$w_{s,t} = \frac{1}{X_t}\alpha\frac{Y_t}{N_{s,t}}, \tag{15}$$

$$w_{b,t} = \frac{1}{X_t}(1-\alpha)\frac{Y_t}{N_{b,t}}, \tag{16}$$

where X_t is the markup, or the inverse of marginal cost.[8]

The price-setting problem for the intermediate good producers is a standard Calvo-Yun setting. An intermediate good producer sells its good at price $P_t(z)$, and $1-\theta, \in [0,1]$, is the probability of being able to change the sale price in every period. The optimal reset price $P_t^*(z)$ solves:

$$\sum_{k=0}^{\infty}(\theta\beta)^k E_t\left\{\Lambda_{t,k}\left[\frac{P_t^*(z)}{P_{t+k}} - \frac{\varepsilon/(\varepsilon-1)}{X_{t+k}}\right]Y_{t+k}^*(z)\right\} = 0. \tag{17}$$

where $\varepsilon/(\varepsilon-1)$ is the steady-state markup.

The aggregate price level is then given by:

$$P_t = \left[\theta P_{t-1}^{1-\varepsilon} + (1-\theta)(P_t^*)^{1-\varepsilon}\right]^{1/(1-\varepsilon)}. \tag{18}$$

Using log-linearized (17) and (18), we can obtain a standard forward-looking New Keynesian Phillips curve $\widehat{\pi}_t = \beta E_t\widehat{\pi}_{t+1} - \psi\widehat{x}_t + u_{\pi t}$, that relates inflation positively to future inflation and negatively to the markup ($\psi \equiv (1-\theta)(1-\beta\theta)/\theta$). $u_{\pi t}$ is a normally distributed cost-push shock.[9]

4.4 Equilibrium

The market clearing conditions are as follows:

$$Y_t = C_{s,t} + C_{b,t}. \tag{19}$$

The total supply of housing is fixed and it is normalized to unity:

$$H_{s,t} + H_{b,t} = 1. \tag{20}$$

4.5 Monetary Policy

Monetary policy is set as follows:

$$R_t = (R_t)^{\rho}\left((\pi_t)^{(1+\phi_\pi)}R\right)^{1-\rho} \tag{21}$$

We consider a standard Taylor rule which responds to inflation and output, with interest-rate smoothing, where $\phi_\pi \geq 0$ measure the response of interest rates to current inflation deviations from the steady state. R is the steady-state interest rate.

[8] Symmetry across firms allows us to write the demands without the index z.

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

4.6 A Macroprudential Rule for the LTV

In standard models, the loan-to-value (LTV) ratio is treated as a fixed parameter, unaffected by economic conditions. However, LTV regulations can be thought of as a tool to moderate credit booms. When the LTV is high, the collateral constraint becomes less restrictive. Since this constraint is binding, borrowers tend to borrow the maximum amount permitted. Conversely, lowering the LTV tightens the constraint, thereby limiting the loans borrowers can obtain.

The literature on macroprudential policies has proposed Taylor-type rules for the LTV, where it reacts inversely to variables such as GDP growth, credit growth, the credit-to-GDP ratio, or house prices. These rules provide a straightforward framework for how macroprudential policy could function in practice. The advantage of such rules lies in their analogy to monetary policy, allowing for a straightforward application of optimal simple rule analysis to both policies and enabling the study of their interactions.

We assume that the macroprudential regulator's objective is to prevent excessive credit growth, which often occurs during economic booms or periods of rising house prices, as agents tend to increase borrowing under such conditions. Consequently, we consider deviations of house prices from their steady-state levels as key indicators of financial instability. Based on this, we formulate a rule for the LTV that makes it responsive to house prices:[10]

$$k_t = k_{SS} \left(\frac{q_t}{q} \right)^{-\phi_{hp}} \tag{22}$$

where k_{SS} is a steady state value for the LTV, and $\phi_{hp} \geq 0,$ measures the response of the LTV to house prices. This kind of rule delivers a lower LTV in house price booms, therefore restricting credit.

We adopt this specific functional form in the spirit of Basel III reports on countercyclical buffers, adapted to the particular context of a low interest-rate environment. The Basel III guidance on countercyclical buffers emphasizes that credit variables or house prices serve as valuable reference points for making buffer decisions. It is important to note that this type of financial constraint does not arise endogenously within the model but is introduced exogenously through regulation. This distinction highlights the difference between market-imposed and government-imposed constraints. In this analysis, we follow the latter approach. Nevertheless, the rationale for LTV policy interventions is supported by the model, given the presence of collateral constraints.

4.7 Welfare-based loss function for evaluating policy rules

To understand the driving forces behind optimal policy in models with collateral constraints, it is essential to discuss the welfare-based loss function derived from this model. In the standard New Keynesian framework, the central bank's objective is to minimize the variability of inflation and output to reduce distortions caused by nominal rigidities and monopolistic competition (Woodford, 2003). However, in models with

[10]We assume that financial regulators adjust the financial constraint cyclically rather than permanently relaxing it to a looser level. This approach is grounded in the idea that moral hazard problems, as described by Kiyotaki and Moore, build up over time rather than materializing immediately when the constraint is temporarily relaxed.

collateral constraints, welfare analysis and optimal policy design extend beyond inflation and output stability.

In such models, constrained individuals face an additional distortion—credit availability governed by collateral constraints—which introduces conflicts and trade-offs between borrowers and savers. Savers may favor policies that mitigate price stickiness distortions, while borrowers, operating under second-best conditions, may prefer policies that alleviate the restrictive effects of collateral constraints. A more stable financial system enables borrowers to achieve smoother consumption patterns, as their consumption is directly tied to credit availability through the collateral constraint.

Consequently, evaluating different policy rules consistently with the model requires deriving a social welfare-based loss function that incorporates the heterogeneity between savers and borrowers. Following Rubio and Yao (2020), welfare can be derived analytically and expressed as a welfare-based loss function in terms of quadratic and gap variables as:

$$W_0 \simeq -\frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta_s^t \left[\widetilde{y}_t^2 + \lambda_\pi \pi_t^2 + \lambda_c \widetilde{c}_t^2 + \lambda_h \widetilde{h}_t^2 \right], \tag{23}$$

where $\widetilde{y}$, $\widetilde{c}$ and $\widetilde{h}$ are the output, consumption and housing gaps, respectively. The relative policy weights are $\lambda_\pi = \frac{\theta\varepsilon}{(1-\theta)(1-\beta\theta)(1+\eta)}$; $\lambda_c = \frac{\alpha(1-\alpha)(2+\eta)}{(1+\eta)^2}$; $\lambda_h = \frac{\alpha(1-\alpha)}{1+\eta}$.

The welfare-based loss function derived from the model has a clear economic interpretation for each of its components. The first two components include the efficient output gap and inflation. These are standard variables in the welfare-based loss functions of a broad class of New Keynesian models. Their inclusion reflects the two distortions associated with price rigidities. First, monopolistic competition introduces a "labor wedge" into the model, causing the level of output to deviate from its efficient level. Second, staggered price setting results in an inefficient dispersion of prices, which is proportional to the rate of inflation.

The second set of terms comprises the consumption and housing gaps, which arise from the heterogeneity between the two types of agents in terms of their access to finance. One group of households is credit-constrained, while the other is not. Savers can insure each other against variations in their housing and consumption bundles, while the quantity of housing collateral limits borrowers' ability to smooth their consumption. The gaps in consumption and housing between optimizing savers and constrained borrowers represent financial stability concerns that policymakers must consider in this simplified model world.[11]

4.8 Baseline Parameter Values

The model above can be simulated by means of choosing a set of parameter values. In this way, we can study the dynamics of the model and make policy experiments. Table 1 presents a summary of the parameter values used in the numerical simulations. The discount factor for savers, β_s, is set to 0.99 to match a 4% interest rate in steady state,

[11] In the real world, financial stability means that the financial system can support the broader economy, both in good and bad times. However, in this simple model, which excludes the behavior of loan defaults and even banks, financial stability is represented by limiting the gap between financially constrained borrowers and financially unconstrained savers.

Table 1. Parameter Values

β_s	0.99	Discount Factor for Savers
β_b	0.98	Discount Factor for Borrowers
j	0.2	Weight of Housing in Utility Function
η	2	Parameter associated with labor elasticity
k_{SS}	0.8	Loan-to-value ratio
α	0.64	Labor share for Savers
X	1.3	Steady-state markup
θ	0.75	Probability of not changing prices
ρ	0.8	Smoothing parameter in Taylor rule
ϕ_π	0.5	Inflation parameter in Taylor rule

as a standard value in most DSGE models. The discount factor for the borrowers in this scenario is set to 0.98. In this model, we need a value for the borrower discount factor, which reflects the fact that they are more impatient than the savers[12] The steady-state weight of housing in the utility function, j, is set to 0.2, in line with previous studies and to generate enough effects from housing. We set $\eta = 1.01$, as in Iacoviello (2005). For the parameter controlling leverage, we set k_{SS} to 0.8, in line with the US data.[13] The labor income share for savers is set to 0.64, following the estimate in Iacoviello (2005). The steady-state markup and the probability of not changing prices are standard values in new Keynesian models. For the Taylor rule, we consider the standard values $\phi_\pi^R = 0.5.$, consistent with the literature.[14]

4.9 Transmission of shocks under collateral constraints

To illustrate dynamics of the model with a collateral constraint, we present impulse responses to a monetary policy shock (a typical demand shock) and a cost-push shock (a typical supply shock). In this way, we can compare the implications of the collateral channel for both types of shocks and see how the cost-push shock is propagated through the collateral constraint, as compared to a demand shock. The left panel corresponds to the monetary policy shock, while the right panel of the figure corresponds to the cost-push shocks. Responses are presented in percent deviations from the steady state.

[12] Lawrance (1991) estimated discount factors for poor consumers at between 0.95 and 0.98 at quarterly frequency. We take the most conservative value.

[13] See Iacoviello (2015).

[14] Note that we assume that the central bank responds only to inflation, for simplicity in our policy exercises.

Figure 2. Impulse responses to a monetary policy shock

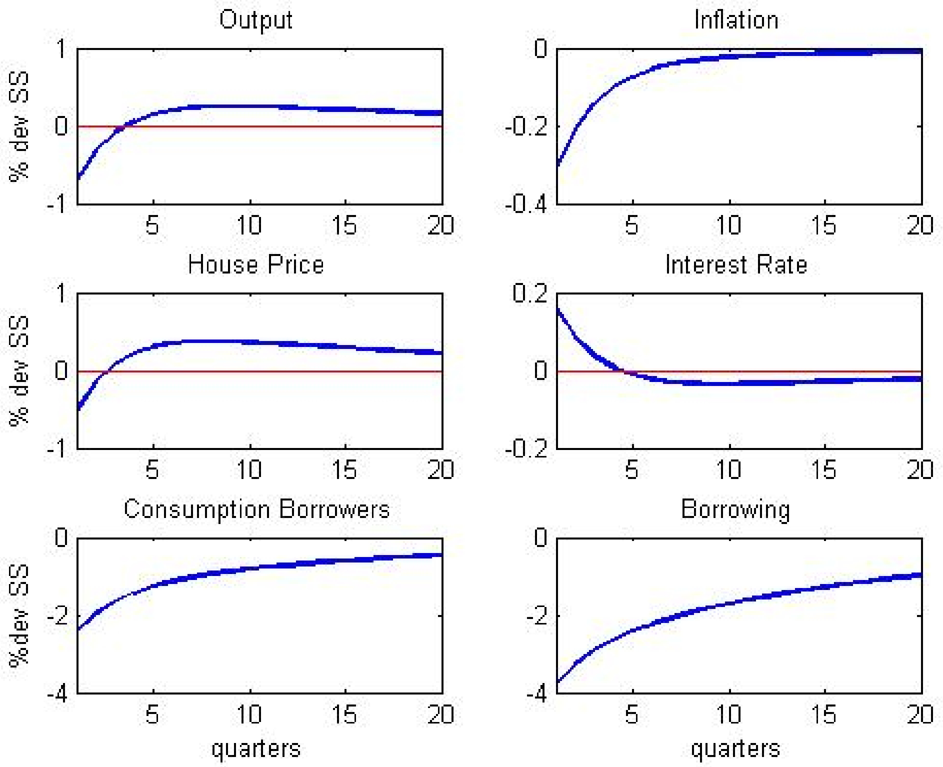
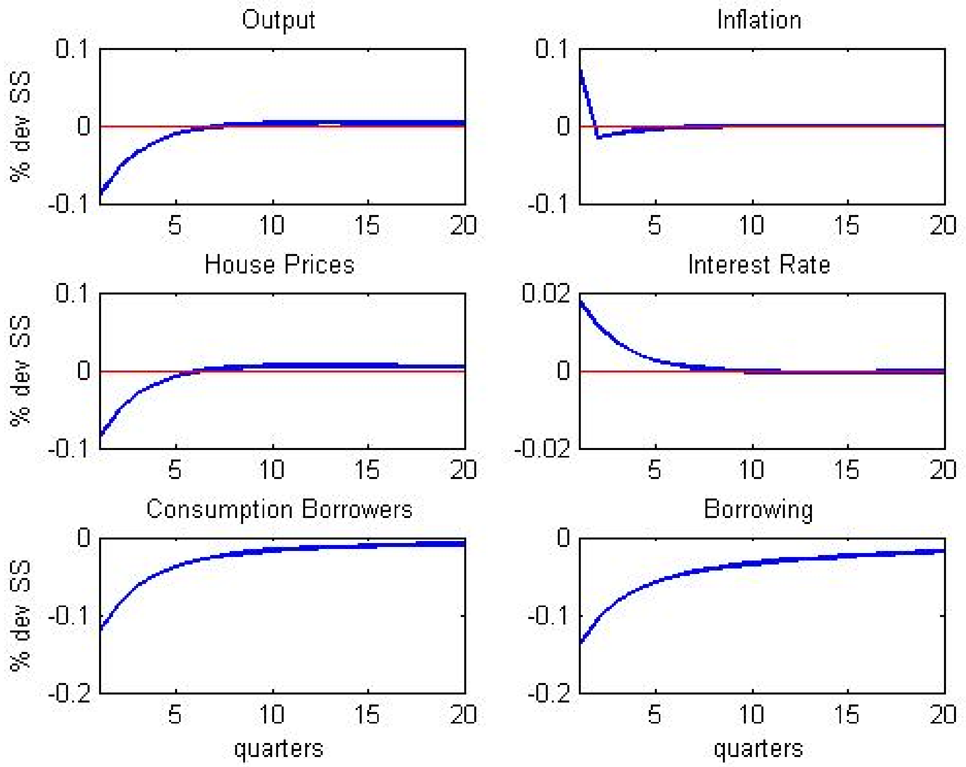


Figure 2 shows the model's impulse responses to a monetary policy shock, represented by an increase in the interest rate (a contractionary shock). It is important to recognize that the collateral constraint amplifies the effect of demand shocks, causing both inflation and the output gap to move in the same direction. In the case of a positive monetary policy shock, the interest rate rises, leading to a decrease in both inflation and the output gap due to its contractionary nature. The effect of the demand shock is amplified because the decline in house prices tightens the collateral constraint at the same time that aggregate demand is under pressure. As a result, inflation decreases more in a model with collateral constraints than in one without this mechanism. Wealth effects are present, and a financial accelerator is at work, arising from the collateral constraint.

Figure 3. Impulse responses to a Cost-Push shock



However, this is not the case for the cost-push shock. Supply shocks present a different scenario. Figure 3 shows the impulse responses to a positive cost-push shock, which is an inflationary shock. This shock pushes inflation up but causes output to decrease, leading these two variables to move in opposite directions. As a result, housing demand contracts, and house prices fall. The collateral constraint becomes more binding for borrowers, which further amplifies the contraction in the economy. In this case, the collateral channel also amplifies the effects of the shock. The decline in aggregate demand exerts a negative effect on inflation, which partially offsets the inflationary impact of the cost-push shock. Taken together, we can conclude that while the impact of demand shocks on inflation is reinforced, the effect of the cost-push shock on inflation is mitigated by the collateral constraint. This creates additional trade-offs in the economy that would not be present in a model without collateral constraints. This insight helps us interpret our numerical results in the following sections.

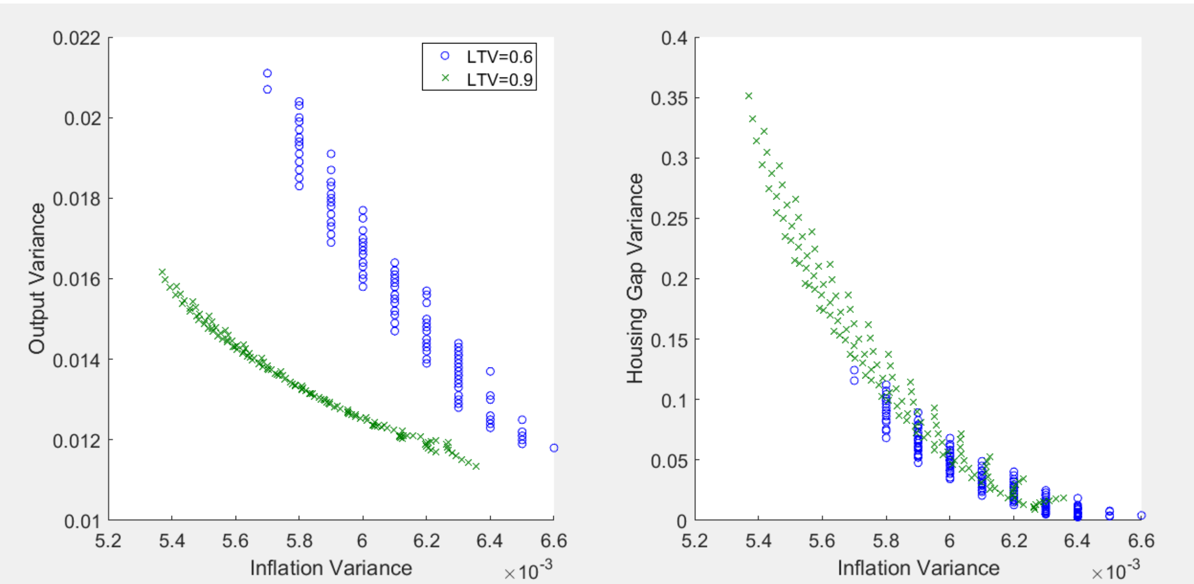
5 Trade-offs in the presence of financial frictions and inflationary shocks

Monetary policy trade-offs are well known in the literature. Taylor (1979) posited that a central bank faces a trade-off between the volatility of the output gap and the volatility of inflation. This trade-off has become known as the Taylor Curve (TC). This trade-off is particularly pronounced in the presence of cost-push (supply) shocks, as a central bank cannot simultaneously reduce the variance of both variables.

However, in the presence of collateral constraints, additional trade-offs may arise that could pose greater challenges for monetary policy. This is particularly evident when we observe the welfare-based loss function presented in equation (23). The welfare-based loss function derived above includes extra components related to financial stability in a simple model without bank loan defaults. The new source of distortion—the collateral constraint—creates conflicts between the welfare maximization of borrowers and savers in the model. Savers may prefer policies that reduce the price-stickiness distortion, as seen in conventional New Keynesian models. Borrowers, on the other hand, are more susceptible to financial shocks due to binding borrowing constraints, and therefore would be better off if financial variables were less volatile and if housing and consumption gaps were reduced. Thus, in a world with collateral constraints, the traditional Taylor curve is only a partial representation of the trade-offs faced by policymakers in the presence of inflationary (cost-push) shocks.

To illustrate this, we construct Taylor curves from simulations of the model, which show not only the relationship between output and inflation volatility, but also their relationship to the housing gap between borrowers and savers. In this way, we extend the notion of the Taylor curve to reflect the new welfare-based loss function that is analytically derived from the model.

Figure 4. Monetary Policy trade-offs under inflationary shocks



Notes: Taylor curves are constructed by plotting the volatility of variables of interest under different Taylor rule coefficients to inflation (ϕ_π) as in Equation 21.

Figure 4 shows the Taylor curve in three dimensions. Taylor curves (or monetary policy trade-offs) are constructed by representing the volatility of the model economy under different monetary policy stances. In our simple model, each point on the curve represents the variability of the variables under consideration for a given coefficient of the Taylor rule and LTV policy. On the horizontal axis, we plot the variance of inflation, while the vertical axes represent the variability of output (left panel) and the variance of the housing gap (right panel), respectively. We repeat this for different values of the inflation coefficient in the Taylor rule, which represents varying degrees of hawkishness in monetary policy towards inflation.

Table 2. Simulated Standard Deviations

LTV	0.7	0.8	0.9
Output	11.78	11.56	11.25
Inflation	7.90	7.85	7.72
Consumption Gap	0.97	1.15	1.54
Housing Gap	1.72	2.09	2.83

Notes: Numbers expressed in the table are in percentage points (%).

The left panel represents the traditional trade-off between inflation and output volatility for monetary policy, while the right panel shows the new trade-off between financial stability, represented by the housing gap, and inflation variability under a cost-push shock. To highlight the role played by the collateral channel, we also plot the Taylor curves under two different levels of LTV, namely 0.9 and 0.6. A higher LTV (0.9) leads to a more pronounced collateral effect. As discussed in the previous section, a collateral constraint amplifies the effects of demand shocks but dampens the effect of supply shocks on inflation.

As shown in the left panel of Figure 4, when the financial accelerator is strong (LTV = 0.9), the entire Taylor curve shifts inwards, resulting in less volatile output and inflation under a certain monetary policy rule. Based on this curve alone, one might conclude that a looser LTV improves the trade-off faced by monetary policy, as monetary policy could achieve a better trade-off between output and inflation volatility during inflationary shocks. However, the new trade-off presented in the right panel tells a different story. The trade-off between inflation and financial stability in the model worsens significantly under a loose LTV. Not only does the slope between inflation and financial stability become steeper, but the range of housing gap volatility also widens considerably under a higher LTV. This suggests that, for a given level of inflation volatility, monetary policy would cause a greater level of financial instability under a looser LTV in the model.

This finding is further supported by Table 2, which presents the simulated standard deviations for all variables that appear in the welfare-based loss function. We report these values for different levels of the LTV (0.7, 0.8, and 0.9). The table shows that, under a given Taylor rule, increasing the LTV improves macroeconomic stability but at the cost of financial stability.

The results in this section strongly suggest that, under inflationary shocks, policymakers face more complex trade-offs than those captured by a simple two-dimensional Taylor curve. Not only do they need to balance inflation and output volatility, but financial stability must also be considered in the optimal policy setting. Importantly, this new trade-off is greatly influenced by the collateral constraint in the economy, highlighting the need for macroprudential policies to complement monetary policy, particularly during inflationary shocks. In the next section, we will discuss how LTV policy, in the form of an LTV rule, can assist monetary policy in achieving its objectives.

6 How should a LTV rule be coordinated with monetary policy?

In this section, we study how an LTV rule should be used to assist the monetary policy rule under an inflationary shock. To answer this question, we explore the optimal simple rule for LTV policy for a given stance of monetary policy against inflation. We assume that the macroprudential authority chooses the optimal response to house prices using the LTV as an instrument. [15]

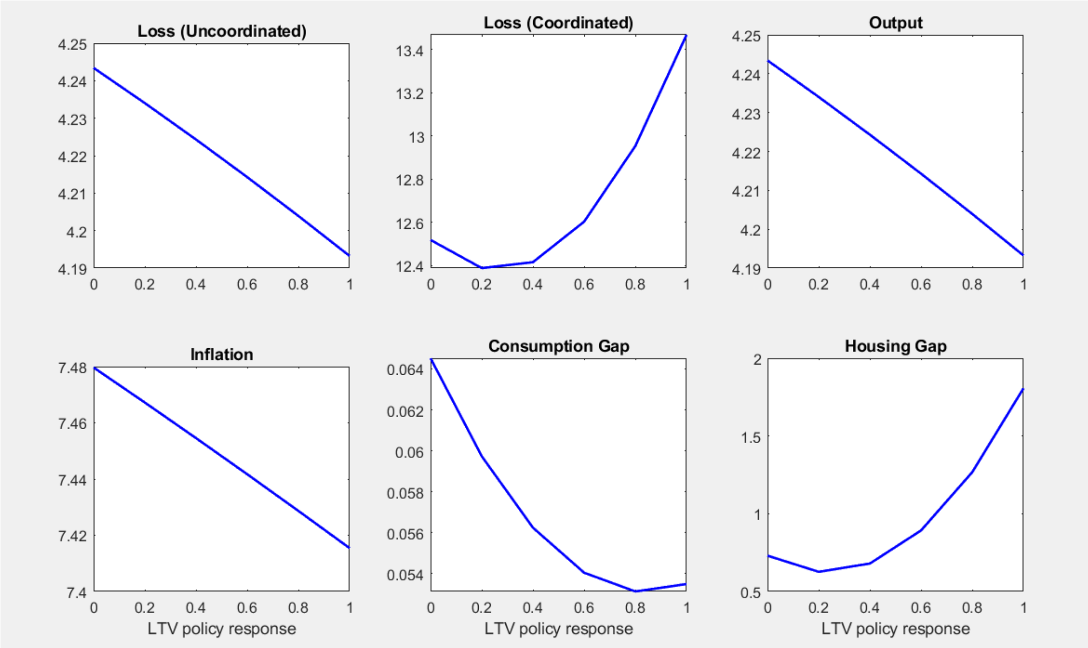
As discussed in the previous sections, inflationary shocks pose a unique challenge to the conduct of macro-stabilization policies, as the shock pushes inflation and output to opposite directions and binding collateral constraints could influence the transmission of inflationary shocks through the tightness of collateral channel. In light of the multiple trade-offs faced by policy makers, the optimal policy needs to find the balance between stabilizing the real economy and financial stability.

Before discussing the full set of optimized simple rule results, we first focus on the simulation results under a single level of monetary policy stance ($\phi\pi = 1$). In Figure 5, we present the total welfare losses and its components - variance of individual variables in the welfare-based loss function (23), obtained under different response coefficients (ϕhp) in LTV policy rule 22. We vary the value of ϕ_{hp} ranging from zero (LTV does not respond to house prices cyclically) [16] to one (LTV is adjusted counter-cyclically against house price fluctuations). In terms of total welfare losses, we also present results in two policy regimes, namely uncoordinated monetary and LTV policy and the coordinated case. In the former case, we assume that LTV policy makers only focus on the gap terms in welfare function (23) and they try to minimize the policy loss that is the sum of financial stability related variables - the consumption and housing gap between borrowers and savers. On the coordinated regime, LTV policy is set to minimize the total welfare-based loss function, which is the weighted sum of all four variables in Equation (23).

[15] We believe that this policy setting is most relevant for many countries' policy context, in which LTV policy and monetary policy are set by different authorities or in a monetary union, such as the Euro area. National macroprudential authorities set their respective LTV but take the monetary policy as given from the European central bank.

[16] In this case, LTV is a constant at its steady state level.

Figure 5. Optimized LTV rule under monetary policy stance



Notes: In these figures, X-axis represents the strength of LTV policy responding to house price fluctuations (ϕ_{hp} in Equation 22). A value of zero, on the one hand, means LTV policy does not respond cyclically to the house price deviation from its steady state, while a value of one, on the other, means LTV responds counter-cyclically to the house price changes. Y-axis in each figure shows the variance of each variable listed in the figure title, except for the first two figures, where welfare losses are shown in the Y-axis, which are the weighted sum of variances of all four variables in the welfare based loss function in 23.

As shown in Figure 5, when the LTV coefficient (ϕ_{hp}) increases, i.e., LTV policy responds more strongly to house prices, both inflation and output volatility go down, but the volatility of the other financial stability relevant variables goes up sharply. Intuitively, tightening LTV policy will increasingly restrict borrowers from buying houses, and therefore larger housing inequality prevails. As a consequence, the lack of housing assets as collateral will further limit the ability of borrowers to smooth their consumption.

As the final step of our optimal policy rule analysis, in Table 3, we report the optimal LTV coefficient ϕ_{hp} and the associated welfare losses with its components under different stances of monetary policy against inflation. In particular, each column in the table corresponds to a certain value of the Taylor rule coefficient ϕ_{π}, ranging from the loosest stance (0.5) to the tightest end (2.5). The row ϕ_{hp} reports the optimized coefficient for house prices in the LTV rule. We compare two LTV policy regimes, with or without coordination with monetary policy. We call it the "Non-coordination regime", in the upper panel, where the LTV policy is narrowly focused on financial stability related terms in the welfare-based loss function, namely the gap terms. In comparison, in the "Coordination regime", the LTV rule is optimized by minimizing the whole welfare-based loss function, in which LTV policy also takes monetary policy objectives into account.

Under the "Non-coordination regime", LTV policy is set independently from monetary policy. Regardless of the monetary policy stance against inflation, LTV policy chooses the strongest response to house prices in the allowed parameter space from our policy

Table 3. Optimized LTV rule under different monetary policy stance against inflation

		ϕ_{π}	**0.5**	**1**	**1.5**	**2**	**2.5**
Non-coordination Regime		ϕ_{hp}^{*}	1	1	1	1	1
	Variance	**Output**	3.68	4.19	4.64	5.11	5.59
		Inflation	0.52	0.47	0.43	0.39	0.35
		Consumption Gap	0.56	0.52	0.62	0.74	0.89
		Housing Gap	18.1	23.5	30.4	37.7	45.1
	Welfare Loss		13.4	13.5	13.8	14.2	14.8
Coordination Regime		ϕ_{hp}^{*}	0.4	0.2	0.2	0	0
	Variance	**Output**	3.73	4.23	4.68	5.15	5.65
		Inflation	0.52	0.47	0.43	0.39	0.35
		Consumption Gap	0.58	0.58	0.66	0.80	0.92
		Housing Gap	8.04	8.15	8.22	8.01	7.60
	Welfare Loss		12.7	12.4	12.2	12.0	11.9

Notes: Numbers expressed in the table are in percentage points ($\%$).

experiments. This policy setting leads to volatile macro variables, varying across different stances of monetary policy. As predicted by the traditional trade-off under a cost-push shock, tightening the monetary policy response to inflation improves the volatility of inflation but at the cost of more volatile output. In addition, a new side-effect of fighting inflation strongly under this regime is that tighter monetary policy increases financial stability concerns sharply, as it is captured by the volatility of consumption and housing gaps in the model. In this case, borrowers not only have to pay higher interest rates on their debts, but also face tougher borrowing conditions under a tighter LTV. This condition makes it more difficult for borrowers to smooth consumption and buy houses. Consequently, the volatility of consumption, the housing gap, and the welfare-based losses rise sharply under this policy regime.

Under the "Coordination regime", by contrast, LTV policy is set with the reflection of the stance of monetary policy. This leads to an overall weaker response to house prices in the optimal LTV rule, and furthermore, the LTV rule softens the stance against house prices when monetary policy fights inflation strongly. Under the coordinated regime, the best welfare outcome lies where monetary policy is still set to its tightest stance against inflation (2.5), but LTV policy accommodates the monetary policy stance by weakening the response to house prices. The policy coordination results in an overall improvement in welfare-based losses, compared to the non-coordination regime.

Conclusion

In this paper, we build a modern macro model that incorporates a housing market and collateral constraints for borrowers. Monetary policy is represented by a standard Taylor rule, which responds to inflation. Macroprudential policy is modeled through a Taylor-type reaction rule for the LTV, responding to house prices. This type of reaction rule encompasses both policy regimes with active (cyclical) and passive (structural) role for LTV. Within this framework, we illustrate that in the presence of inflationary shocks, the trade-offs faced by monetary policy go beyond the conventional inflation-output trade-off. They also involve a new trade-off between real economic activity and financial stability. The added challenge of maintaining financial stability under inflationary shocks calls for the use of macroprudential policies. In this context, LTV policy emerges as a potential complement to monetary policy to achieve the conflicting objectives of stabilization. Through an optimal simple rule exercise, we demonstrate that policy coordination between monetary and macroprudential policies results in an overall improvement in welfare-based losses, compared to a non-coordinated policy regime. In particular, the LTV rule is active when monetary policy responds weakly to inflation shocks, but the LTV rule is passive when monetary policy chooses to be hawkish towards inflation.

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