Optimal Monetary Policy, Macroprudential Instruments, and the Credit Cycle

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In Partial Fulfillment of the Requirements for the Master of Science in Economics

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Department of Economics
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7th of June 2019
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Abstract

I study optimal monetary and macroprudential policies in a New Keynesian DSGE framework with leverage-constrained banks. In particular, I assess the desirability of alternative operational policy rules when the economy is hit by mortgage default shocks and show that their implications for inflation dynamics and policy trade-offs depend on whether the shocks originate in the household sector or in the entrepreneurial sector of the economy. Moreover, I find that the strategy of "leaning against the wind" (LAW) of credit growth delivers systematically poorer stabilization outcomes than standard flexible inflation-targeting when there exists a non-trivial trade-off between stabilizing output and inflation, but outperforms conventional monetary policy for shocks that generate a comovement between the two, irrespective of the real or financial nature of the shock.

I show that optimal macroprudential regulation that is as concerned with output as monetary policy can drastically reduce, and in many cases completely eliminate, the incentive to lean against the wind. I argue that this is due to the ability of full-fledged optimal macroprudential policy to break the favourable complementarity between stabilizing credit growth and stabilizing output growth which underlies the incentive to lean against the wind. Macroprudential policy proves a superior substitute to LAW because it can achieve the same financial stability objectives without systematically imposing costs in terms of price stability.

Keywords: Monetary policy, macroprudential regulation, banking, financial frictions
1. Introduction

Concerns that an excessively procyclical financial sector might amplify the effects of real and financial disturbances (Bernanke et al., 1996, Lorenzoni, 2008, Brunnermeier et al., 2012) have drawn policymakers’ attention to a variety of instruments designed to ensure resilience and stability of the financial system (Claessens, 2014, Cerutti et al., 2017).

Figure 1 shows how financial aggregates comove with economic activity over the business cycle. When real output rises above potential, the estimated cyclical component of real house prices, as a proxy for aggregate asset prices, and leverage in the U.S. economy, as measured by the ratio between the amount of loans extended to non-financial institutions and nominal GDP, swing above their long-run equilibrium. Conversely, economic slack associates with protracted periods of depressed asset prices. It is useful to notice how peaks and troughs in leverage in the figure tend to lag movements in asset prices, suggesting that valuation changes that push asset prices far above or below trend can predict considerable variation in the relative size of the financial sector.

![Figure 1: Cyclical Properties of Real Asset Prices and Credit in the U.S.](image)

Notes: Shaded areas indicate US recessions (NBER). Quarterly data, 1985Q1-2018Q3. Trend component of credit-to-GDP and real house prices estimated by applying the Hamilton (2018) filter to the raw time series $\{y_t^{2018Q3}\}_{t=1985Q1}$ as $y_{t+h} - \hat{y}_{t+h} = x_t' \hat{\beta}$, where $x_t = (y_t, ..., y_{t-p+1}, 1)'$ and $\beta = (\beta_0, ..., \beta_p)$, with $h = 8$ and $p = 4$ (the first $h + p - 1$ observations are lost in estimation). Sources: Bank for International Settlements; U.S. Bureau of Economic Analysis; U.S. Congressional Budget Office; OECD; author’s calculations (see Figure 1 in Data Construction and Sources).

To add perspective on the link between economic performance, asset prices, and leverage, Figure 2 provides a graphical representation of the credit cycle which sets the Global Financial Crisis (GFC) apart from the preceding one. In the run-up to both crises, increasing debt-to-equity ratios were paralleled by neither a tightening of credit conditions nor a rise in perceived funding risk, as economic activity was solid and asset prices buoyant. Systemic risk was in fact building up in an apparently low-risk environment. But while for the case of the Dot-com Bubble, risk remained low through the cycle, the same did not hold for the recent crisis. In the latter, the cycle went in reverse when the net worth of an increasing number of highly-leveraged borrowers plunged underwater around the end of the summer of 2008, which resulted in many commercial banks facing a wild spike in losses on loans secured by real-estate collateral (solid blue line). Consequently,
risk premia rose sharply and credit conditions tightened. Faced with a shortage of liquid funds, banks whose capital was poor-quality and scarce engaged in sizeable contractions of their loan portfolios, reducing refinancing opportunities on outstanding loans and growing unwilling to finance new ones. But as many banks reacted simultaneously to the shock, the contractionary action of the marginal bank affected the credit market equilibrium systemwide.

Figure 2: Financial Conditions and Charge-Off Rate on Loans Secured by Real Estate in the U.S.

In the aftermath of the GFC and in the light of the profound impact that such disruptive dynamics had in several countries of the world over the past decade, the agenda of many a financial supervisory authority has witnessed to a shift from purely micro-based financial regulation to a more macroprudential approach. This novel perspective is motivated by recognition that externalities associated with the borrowing and risk-taking behaviour of individual credit market participants can lead to the build-up of large-scale imbalances that are impervious to detection in the restricted partial equilibrium setting in which microprudential regulation operates (De Nicolo et al., 2012, Galati and Moessner, 2013).

For example, a number of papers have studied the consequences of moral hazard and correlated bank risk as well as pecuniary externalities arising from fire sales, e.g. Farhi and Tirole (2012), Caballero and Simsek (2013). These sources of inefficiency arise from favourable ex-ante incentives to excessive risk-taking in normal times, but in the case of a downturn they can severely impair the ex-post borrowing capacity of banks and borrowers in the non-financial sector on a large scale. Countercyclical capital requirements are aimed at ensuring that financial intermediaries remain sufficiently liquid through downturns and limit their short-term borrowing needs during economic booms.

A further rationale for the use of ex-ante quantity restrictions, such as maximum loan-to-value (LTV) ratios for borrowers in the non-financial sector, is provided by a class of aggregate demand externalities (Farhi
generated by the failure of individual market participants to internalise the effects of their decision to deleverage when output is demand-constrained, as it is the case, for example, at the zero lower bound (ZLB) of the interest rate. In this region, the policy rate is constrained from below and monetary policy cannot effectively track the efficient rate of interest by means of conventional policies.

Nonetheless, however justified, the macroprudential approach to financial regulation has paved the way for a major reassessment and overhaul of the policy landscape in which macroeconomic stability and financial stability are to be conceived of and ultimately achieved.

Indeed, before the GFC a long-standing consensus held sway among central bankers and scholars concerning the ability, and therefore the role, of monetary policy in explicitly confronting financial stability concerns and preventing financial distress, such that the best stance of policy was mostly believed to be that of ‘mopping up’ in the aftermath of events characterised by financial turmoil, as exemplified the bursting of an asset price bubble. But as the recent crises has shown, the ability of the central bank to ‘mop up’ might be severely impaired, for instance, by the interaction of the ZLB with protracted market pessimism and anchored inflation expectations to make the flattening of the yield curve a difficult task for monetary policy.

Similar considerations have contributed to a major revival of the debate on whether a strategy of ‘leaning against the wind’ (LAW) of rising asset prices and debt accumulation can effectively prevent the occurrence of such events and has sparked a renewed interest on the possibility that monetary policy take on a more proactive role in ensuring financial stability. Nevertheless, a remarkable degree of uncertainty continues to surround the extent to which monetary policy should steer the short-term interest rate to keep financial instability in check. The introduction of macroprudential policy in the policy landscape begs the question of whether LAW and active macroprudential policy can be conceived as complements towards the goal of financial stability.

Figure 3 illustrates the evolution of financial distress and monetary policy uncertainty in the U.S. As it appears from the figure, the newspaper-based monetary policy uncertainty index soared at the very beginning of the GFC, an indication that the best course of action for monetary policymakers vis-à-vis distressed financial intermediaries might not be obvious in real time, neither for policymakers themselves nor for the general public. To the extent that monetary policy uncertainty can have negative macroeconomic effects in its own right (Husted et al., 2017), investigating the optimal stance of policy in a model with distressed banks can shed light not only on the menu of opportunities available to central banks when financial distress breaks out, but also on the expectations that market participants can form under these circumstances.

Taking stock of the foregoing remarks, I study the gains in terms of macroeconomic stability of both credit demand-side and credit supply-side macroprudential instruments and their interaction with the conduct of monetary policy when the economy is subject not only to standard real shocks, but also to purely financial shocks that have the potential to disrupt credit intermediation. In particular, I focus on mortgage default shocks that unexpectedly redistribute wealth from leverage-constrained banks to defaulting borrowers.

To this purpose, I use a dynamic stochastic general equilibrium (DSGE) model with a banking sector and financial market imperfections and operationalize it for policy analysis by enriching it to accommodate stickiness in price-setting and a prudential authority.

This modelling framework, where the financial sector of the economy is highly fragile and prone to disruptions, provides a most appreciable setting in which to study the interaction between monetary and macroprudential policy.

Moreover, I provide for a vast macroprudential toolkit, whereby the prudential regulator can avail itself of 5 instruments: three maximum LTV ratios on residential real estate, commercial real estate, and entrepreneurial capital, and two countercyclical requirements on loans to entrepreneurs and loans to households\(^1\), while I assume for simplicity that monetary policy operates only through manipulation of the short-term rate of interest in accordance to a feedback rule. As it appears, each macroprudential measure targets a corresponding source of financial unbalance in a specific segment of the market for funds. On the contrary,

\(^1\)Albeit other and increasingly more sophisticated instruments have been devised, countercyclical capital requirements and maximum loan-to-value ratios remain the most widely used in advanced economies to the present day (Cerutti et al., 2017).
monetary policy has the potential to enter ‘all of the cracks’ (Stein, 2013). Through the use of many instruments that ramify in all sectors of the economy (the household sector, the entrepreneurial sector, and the banking sector), I allow for macroprudential policy to gain the potential to enter many ‘cracks’, reducing the difference in the scope of the two policies.

Importantly, although the literature on macroprudential policy has grown at a sustained pace (Galati and Moessner, 2013), the existing studies of macroprudential policy have mainly focused on single macroprudential instruments or small combinations thereof, in which capital requirements and loan-to-value ratios are mostly studied in isolation, with few exceptions, e.g. (Chen and Columba, 2016). In contrast, the unified modelling framework I present allows to quantify the costs and benefits in terms of macroeconomic stability of alternative configurations of the interaction between monetary and macroprudential policies by looking at both sides of the credit market. On the grounds that the effectiveness of these instruments is liable to hinge crucially on the nature of the shocks the economy is susceptible to and the relationship between the two policies, I experiment with several combinations of shocks and policy stances. This strategy ensures internally consistent trajectories of the variables of interest under separate policy stances and guarantees comparability of outcomes across interaction schemes and shocks within a single environment.

In addition to preparing a rich framework for the analysis of optimal monetary and macroprudential policies, I allow the prudential authority to share a concern for output stabilization with monetary policy, which emerges to be a crucial feature for the effectiveness of macroprudential policy in the model at hand, because it allows macroprudential policy to supplant the desirable feature of LAW, namely its ability to stabilize credit

\[\text{Notes:} \text{ Shaded areas indicate US recessions (NBER). Monthly data, January 1995-July 2017. The monetary policy uncertainty index is constructed by searching for keywords related to monetary policy uncertainty in the New York Times, Wall Street Journal, and Washington Post. A positive value of the index suggests below-average monetary policy uncertainty, while negative values indicate the opposite. The measure of financial stress is constructed by aggregating several yield spreads and interest rates, as well as other indicators related to liquidity and solvency. A positive value of the index suggests below-average financial market stress, while negative values indicate the opposite. Sources: Federal Reserve Bank of St. Louis; Husted et al. (2017); author’s calculations (see Figure 3 in Data Construction and Sources).} \]

\[\text{2This view has been questioned in Svensson (2018) and International Monetary Fund (2015). See Section 2.}\]
growth and output growth due to the strong correlation between the two in a model in which mechanisms that propagate financial shocks hold sway.

Lastly, my analysis reconnects with the contribution of Gambacorta and Signoretti (2014), who found strong support for monetary policy rules augmented with asset prices, but only studied them in “normal times”. My contribution partly takes on their work, and offers a characterisation of the effectiveness of LAW in financially distressed times.

The remaining of this paper is organised as follows. Section 2 provides an extensive survey of the DSGE literature related to financial frictions and the interaction between monetary and macroprudential policy. Section 3 presents the modelling framework, the agents’ optimization problem, and the equilibrium in the model. Section 4 briefly presents the calibration of the model. Section 5 describes the mechanisms of transmission of the shocks. Section 6 presents the results, both in terms of loss functions and welfare. Section 7 explores the robustness of the results. Section 8 concludes.

### 2. Related Literature

Until the late 1980s, financial markets were not integrated components of early business-cycle models of general equilibrium, but rather a structureless veil. This implicit neglect for financial markets was compatible with the assumption of perfect markets, in which economic agents’ net worth is unaffected by their sources of finance (Modigliani and Miller, 1958), but irreconcilable with considerations of market failures such as asymmetric information (Akerlof, 1970), principal-agent problems (Jensen and Meckling, 1976), and adverse selection (Stiglitz and Weiss, 1981) applied to financial contracts.

Over the past thirty years, a growing body of literature has addressed the business-cycle implications of changes in agents’ financial position for the determination of credit-market conditions in the presence of market failures. In Bernanke and Gertler (1989), Bernanke et al. (1996), and Carlstrom and Fuerst (1997) lenders shoulder dead-weight agency costs in the attempt to monitor borrowers’ behaviour and credit-worthiness. For this reason, an adverse shock to borrowers’ equity raises agency costs, as the default probability of the borrower increases. Lowered credit-worthiness is reflected into higher borrowing costs which, holding borrowing needs constant, require the borrower to curb spending and investment. Bernanke et al. (1999) would subsequently embed this financial accelerator derived from partial equilibrium considerations in a full-fledged New Keynesian general equilibrium model.

In Kiyotaki and Moore (1997) credit cycles are generated by a collateral amplification mechanism: when the value of assets pledged as collateral declines for some exogenous reason (e.g. a productivity shock), firms subject to collateral constraints are forced to de-leverage to satisfy the collateral requirement. By deleveraging, they hurt future revenues, which further depresses their equity. Their ability to invest is therefore impaired not only in the present, but also in the future.

Another strand of the literature has explored households’ consumption of non-durables to explain fluctuations in aggregate demand.

In two influential models, Iacoviello (2005) and Iacoviello and Neri (2010) concentrate their attention on nominal debt and collateral constraints in the US housing market to explain the observed ‘acceleration’ of aggregate demand in response to swings in house prices and the ‘decelerating’ effect that supply shocks have on economic activity.

In the aftermath of the GFC, researchers have explored further the role of housing in quantitative macroeconomic models (e.g Justiniano et al. (2015)) and investigated the connection between credit-market conditions, housing collateral valuation, and aggregate fluctuations (see Mian and Sufi (2018) for a comprehensive overview).

However, the models described thus far abstract from considering financial intermediation explicitly. Most importantly, they address market imperfections that amplify shocks whose exogenous origin lies outside the financial sector itself. In fact, the seminal contributions by Jermann and Quadrini (2012) and Brunnermeier and Sannikov (2014) underscore the importance of taking into consideration not only shocks that the financial sector propagates, but also those that arise in it. Another body of research concerned with financial market imperfections has in effect endeavoured to bring financial intermediaries to the fore, their behaviour being decisive for the interaction between financial markets and macroeconomic dynamics.
In an early attempt to model financial intermediation, Holmstrom and Tirole (1997) devise a theoretical model in which banks face a moral hazard problem in monitoring the firms they finance and deposit investors face a moral hazard problem because bankers have an incentive to avoid costly monitoring of firms’ projects financed with investors’ loanable funds.

The double moral hazard problem has been used as the main mechanism in a number of papers interested in bank capital, for instance Chen (2001), and subsequently Meh and Moran (2010). In the latter, the authors show how bank capital can play a major role in the amplification of shocks, as banks, in the attempt to recover their balance sheet position harmed by a negative shock, curtail loans to the productive sector. The drop in aggregate investment that ensues lowers bank earnings, which makes the crunch even more severe in later periods.

Taking stock of such amplification mechanisms, numerous researchers have aimed attention at policy instruments which can keep their strength in check for the purpose of stabilising the macroeconomy in the face of financial instability. Before the macroprudential approach to financial stability entered established itself as a viable policy option, papers such as Cogley (1999), Bernanke and Gertler (2001), and Gilchrist and Leahy (2002) were concerned with whether it was desirable for monetary policy to thwart asset price movements, the so-called strategy of leaning against the wind (LAW). They all concluded that central banks ought not deviate from their flexible inflation targeting objective. This view remained mostly dominant until it was challenged by the writings of Gambacorta and Signoretti (2014), who argue that some degree of LATW can have desirable welfare effects, and Filardo and Runcharoenkitkul (2016), who maintain that sustained monetary policy action to rein in asset prices and credit booms can smooth the financial cycle by reducing its unconditional amplitude over the long run. For this reason, their empirical analyses indicate that the benefits of LAW for macroeconomic stability are understated when a short-run perspective, restricted to one-off interventions on the policy rate, is adopted.

On the contrary, Svensson (2016, 2017, 2018) shows that LAW policies fail to pass the test of cost-benefits analysis, with the ability of short-term rates to shrink the probability and the magnitude of a crisis being diminutive relative to their cost and hinting to the possibility that monetary policy sets itself too tall an order if it attempts to systematically achieve financial stability. In their studies of rational asset price bubbles and long-term debt and using different arguments, also Gali (2014) and Gelain et al. (2018) seem to question the case for leaning.

The case for leaning remains a hotly debated issue also in policy circles: Bank of International Settlements (2014) advocates a more proactive role for monetary policy in addressing risky balance sheet volatility, while International Monetary Fund (2015) has guarded against such a stance, concluding that pass-through from interest rates to financial risk-taking is limited.

In his appraisal of the topic, Smets (2014) suggests that monetary policy-makers should ‘keep an eye’ on developments in financial markets, but maintain macroprudential tools as their main instruments.

A series of papers has built on the models described above to gain insight into the effectiveness of the macroprudential tools of interest for my analysis for financial-cycle stabilisation.

Lambertini et al. (2013) and Rubio and Carrasco-Gallego (2014) analyse the effect of loan-to-value ratios in economies à la Iacoviello (2005) and Iacoviello and Neri (2010), respectively, and assess their implications for agents’ welfare. While both conclude that the use of LTV caps that respond to credit growth is Pareto-improving, the latter attests that the gain in social welfare is concave in the reaction to credit growth, the welfare gains accruing to borrowers coming at the expense of savers’ own welfare. As the borrowers’ gain in welfare is large enough to compensate savers, the LTV instrument yields desirable results. In an estimated model building on Iacoviello and Neri (2010) and using Swedish data, Walentin (2014) documents how more accommodative LTV caps can significantly intensify the real effects of monetary policy shocks. In estimated open-economy model of New Zealand that borrows mainly from Iacoviello (2005) and Galí and Monacelli (2005), Funke et al. (2018) find that LTV restrictions implemented in 2013 in New Zealand have barely affected consumer prices, but effectively lowered booming house prices. In this sense, LTVs have not interfered with the price stability objective of monetary policy. Using narratively high-frequency identified data on macroprudential shocks on a sample of advanced and emerging economies, Richter et al. (2019) find the same price neutrality of macroprudential policy, yet find statistically significant negative effects of macroprudential LTV policy on output in the short-run. However, In the sample of economies, these effects are measured to be
On the contrary, the authors suggest that maximum LTV ratios effectively stabilise house and credit growth.

Christensen et al. (2011) revisit the intuition by Meh and Moran (2010) to investigate the effects of regulation of bank leverage. In these two models, bank capital provisions redress the moral hazard between bankers and the entrepreneurs, increasing the ‘skin in the game’ for banks in times of economic distress. The double moral hazard problem is used also by Haavio et al. (2016) to assess the role of government capitalization of banks and by Silvo (2019) to study Ramsey-optimal macroprudential and monetary policies with capital requirements and their performance in comparison to simple rules. Her results suggest that simple rules are not robust to the source of fluctuations: a flexible inflation targeting monetary policy regime may need to accommodate deviations to contrast adverse financial shocks, while countercyclical capital requirement regulation may collide with traditional stabilisation objectives of monetary policy when the economy is hit by a real shock. On the contrary, she finds that Ramsey-optimal policies are robust to the sources of fluctuations if the social planner can conduct macroprudential and monetary policy jointly, as they allow the Walrasian first-best allocation.

On a similar note, De Paoli and Paustian (2017) and Gelain and Ilbas (2017) make use of yet another source of agency problems. The friction these models envisage originates from the costly monitoring effort of depositors in Gertler and Karadi (2011). This modelling device indirectly creates a direct interdependence between the balance sheet of the bank and that of the saver. Bailliu et al. (2015) and Leduc and Natal (2018) examine macroprudential policy and monetary policy in a setting à la Bernanke et al. (1999), in which entrepreneurs’ borrowing costs increase as their equity deteriorates, a reflection of the increase in the external finance premium. Angelini et al. (2014) build on the rich model of Gerali et al. (2010) to investigate the dynamic effects of capital requirements on the conduct of monetary policy, and citetangeloni2013 are concerned with optimal policy when banks runs and risks from liquidity dry-ups arise endogenously to banks’ behaviour. The model by Gerali et al. (2010) is implemented also by Chen and Columba (2016) to probe extensively the welfare effects that a set of demand-side macroprudential instruments and one lender-oriented tool, mortgage risk-weight. However, they do not study capital requirements.

Critically, while one share of these papers seem to support the idea that monetary policy and macroprudential policy should have different objectives, the other stresses the necessity for both authorities to respond to at least one common target variable in a coordinated effort.

### 3. The Model

I extend the flexible-price model by Iacoviello (2015) so as to accommodate sticky prices and the presence of a prudential regulator.

Imagine a cashless economy\(^3\) populated by patient and impatient households, bankers, entrepreneurs, and retailers\(^4\). Agents in the model are infinitely-lived and have unit measure. Time is discrete and refers to quarters of a year. In this model debt contracts are signed in nominal terms and houses are a productive asset whose value needs to be collateralised for borrowers to access loans. The interest rate paid to household depositors and the interest rate paid by household borrowers are pre-determined, while the interest rate on the loans issued to entrepreneurs is not.

As in Iacoviello (2005), there exist two types of households. One of the two types discounts future utility more heavily than the other. They are impatient households. The remaining fraction of households is patient. Heterogeneity in discount factors generates gains from trading credit flows. Bankers borrow deposits from patient households, who are net savers in equilibrium, and extend loans to the productive sector, the entrepreneurs, and to the non-productive sector, the impatient households, who are net borrowers. Entrepreneurs

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\(^3\)Woodford (1998) shows how movements in money demand in the absence of monetary frictions bear little implications for equilibrium inflation if it is assumed that the monetary authority attempts to track the efficient rate of interest by means of feedback rules. As noted by Woodford himself, the cashless limit provides an approximation theorem. I assume that this approximation is sufficiently accurate in the present setting.

\(^4\)As noted by Fuerst (1994), the presence of financial intermediaries that attract loanable funds can be justified by an information structure by which bankers specialise in the assessment of risky loan projects and enforcement of the corresponding loan contracts, reducing the need for a direct connection between lenders and borrowers. In the present model, such need is completely absent.
hire the factors of production in competitive markets and sell the intermediate output they produce to monopolistic retailers. Retailers differentiate it costlessly and sell it at a mark-up over the marginal cost of production on the market for final goods. Staggered price contracts follow Calvo (1983) and Yun (1996), so that in each period only a stochastic fraction of retailers receives a signal to re-optimize their nominal price. Staggered price adjustment implies that the short-run non-neutrality of money allows the monetary policy conducted by the central bank to have real effects (Christiano et al., 2005).

The model features three sources of financial frictions, in the form of collateral constraints: on the one hand, entrepreneurs are constrained in the amount of loans they can borrow by the value of their commercial real estate, and so are impatient households with respect to their residential real estate. On the other hand, bankers are constrained in their ability to leverage: they can only issue deposit liabilities up to a fraction of the value of their loans to impatient households and entrepreneurs. My investigation sheds light on the consequences of including macroprudential regulation in the presence of such frictions in a model with competitive banks.

3.1. Patient Household

Patient households are net-savers in equilibrium. They choose the path of consumption \( [C_{i,t}]_{t=0}^{\infty} \), physical capital \( [K_{i,t}]_{t=0}^{\infty} \), capital utilization utilization rate \( [z_{K}H_{i,t}]_{t=0}^{\infty} \), real deposits \( [d_{i}]_{t=0}^{\infty} \), residential real estate \( [H_{i,t}]_{t=0}^{\infty} \), and labour hours \( [N_{i,t}]_{t=0}^{\infty} \) to maximize lifetime utility

\[
\mathbb{E}_t \left\{ \sum_{i=0}^{\infty} \beta^i H_t \left( A_{p,t+1}(1-\eta)\log(C_{H,t+1}-\eta C_{H,t+1}) + jA_{j,t+1}A_{p,t+1} \log H_{H,t+1} + \tau \log(1-N_{H,t+1}) \right) \right\}
\]

subject to a sequence of budget constraints, as expressed in real terms

\[
C_{H,t} + \frac{K_{H,t}}{A_{K,t}} + d_{t} + q_{t}(H_{H,t} - H_{H,t-1}) + ac_{KH,t} + ac_{DH,t} = \left( R_{M,t}z_{KH,t} + \frac{1-\delta_{KH,t}}{A_{K,t}} \right) K_{H,t-1} + \frac{R_{H,t-1}}{\pi_{t}} d_{t-1} + w_{H,t}N_{H,t} + \Pi_{H,t},
\]

where \( \mathbb{E} \) denotes the mathematical expectation operator and \( C_{H,t} = \left( \int_{0}^{1} C_{j,t} j \, dz \right) \frac{1}{\pi_{t}} \) is a CES aggregate consumption index over a continuum of goods \( j \in [0,1] \) the households consumes, with \( \epsilon \) being the elasticity of substitution between good varieties. The external habit stock (Abel, 1990) is assumed to be proportional to lagged aggregate consumption index over a continuum of goods \( j \in [0,1] \) the households consumes, with \( \epsilon \) being the elasticity of substitution between good varieties. The external habit stock (Abel, 1990) is assumed to be proportional to lagged aggregate consumption, it is unaffected by any one agent’s decision, and it equals \( \eta C_{H,t-1} \). The term \( 1-\eta \) is a standard shift term which ensures which ensures that the non-stochastic steady state the marginal utility of consumption does not depend on habit formation. The household accumulates residential real estate (‘houses’), saves in physical capital, with one-period time to build, and supplies labour \( N_{t} \) to the entrepreneur. \( A_{p,t} \) is a shock to the preferences for consumption and housing jointly, while \( A_{j,t} \) is a shock that affects only the preference parameter \( j \), which determines the taste for housing in the utility function. The parameter \( \tau \) determines the disutility weight attached to the supply of labour.

From equation (2), the household buys consumption goods, accumulates capital \( K_{t} \), deposits its savings at financial intermediaries (‘banks’), and acquires units of housing at a real price \( q_{t} \). As housing is in fixed supply, its nominal price \( P_{t} \) is solely determined by demand at time \( t \). Houses are flexible-priced and do not depreciate. On the income side, the household accrues a pre-determined gross interest payment \( R_{H,t} \frac{d_{t-1}}{\pi_{t}} \) on deposits held at the bank from the previous period, earns the gross return \( R_{M,t} \) on the capital services \( z_{KH,t}K_{H,t} \) rented to entrepreneurs the current market value of the housing stock held from the previous period, the undepreciated fraction of its capital stock in the previous period, and the gross interest payment on deposits. The terms \( ac_{KH,t} \) and \( ac_{DH,t} \) are standard external convex adjustment costs associated with changes in the stock of capital and portfolio of deposits. Labour income \( w_{H,t}N_{H,t} \) and profits from the retailers \( \Pi_{H,t} \) close the budget constraint of the patient household,
3.2. Impatient Household

The impatient households’ utility function is symmetrical to their patient counterpart’s. However, on the grounds that they are net borrowers in equilibrium, they neither accumulate capital nor deposit any savings at banks, but rather choose how much to borrow. Hence, they choose the path of consumption \([C_{S,t}]_{t=0}^\infty\), real loans \([l_t]_{t=0}^\infty\), residential real estate \([H_S]_{t=0}^\infty\), and labour hours \([N_S]_{t=0}^\infty\) to maximize lifetime utility

\[
E_t \left\{ \sum_{i=0}^{\infty} \beta_t^i \left[ (1-\eta) \log(C_{S,t+i} - \eta C_{S,t+i-1}) + jA_{t+i} \left( A_{p,t+i} \log(H_{s,t+i}) + \tau \log(1-N_{S,t+1}) \right) \right] \right\}
\]

subject to a sequence of budget constraints and borrowing constraints, as expressed in real terms

\[
C_{S,t} + q_t(H_{S,t} - H_{S,t-1}) + \frac{R_{S,t-1}}{\pi_t} l_{S,t-1} - \epsilon_{H,t} + a c_{S,t} = l_{S,t} + \omega_{S,t} N_{S,t},
\]

\[
l_{S,t} \leq \rho_S \frac{l_{S,t-1}}{\pi_t} + (1-\rho_S)m_S A_{MH,t} \varepsilon_{t} \left[ \frac{q_{t+1} \pi_{t+1}}{R_{S,t}} H_{S,t} \right].
\]

The budget constraint of the impatient household (4) contains a new term \(\epsilon_{H,t}\) on the expenditure side, which is a redistributive shock from the bank to the household that occurs when the household defaults on the mortgage contract it has signed with the bank, for some unmodelled exogenous reason. Also the impatient household decides how much to invest and consume, and must set aside enough resources to repay loans \(\frac{R_{S,t-1}}{\pi_t} l_{S,t-1}\) and convex adjustment costs \(a c_{S,t}\) to manage its portfolio of loans. On the income side, the impatient household receives labour income payments and loans from the banks. This household borrows against the expected value of the their stock of real estate, as shown in (5), where the persistence parameter \(\rho_S\) captures inertia in the collateral constraint, \(m_{S,t}\) is an LTV ratio, and \(A_{MH,t}\) is a shock to the the borrowing standards that proxies, for a given collateral value, a sudden change in screening practices on the part of the bank.

3.3. Banker

The banker intermediates funds between savers and borrowers\(^5\). They choose the paths of consumption, i.e. retained earnings, \([CB]_{t=0}^\infty\), real deposits \([d_t]_{t=0}^\infty\) from patient households, real loans to entrepreneurs \([l_E]_{t=0}^\infty\) to maximize utility

\[
E_t \left\{ \sum_{i=0}^{\infty} \beta_t^i (1-\eta) \log(C_{B,t+i} - \eta C_{B,t+i-1}) \right\}
\]

subject to a sequence of budget constraints and borrowing constraints, as expressed in real terms

\[
C_{B,t} + \frac{R_{H,t-1}}{\pi_t} d_{t-1} + \frac{R_{E,t}}{\pi_t} l_{E,t-1} + l_{S,t} + a c_{DB,t} + a c_{EB,t} + a c_{SB,t}
= d_t + \frac{R_{E,t}}{\pi_t} l_{E,t-1} + \frac{R_{S,t-1}}{\pi_t} l_{S,t-1} - \epsilon_{E,t} - \epsilon_{H,t},
\]

\[
d_t \leq \rho_D \left[ \frac{d_{t-1}}{\pi_t} + \frac{l_{E,t-1}}{\pi_t} - \frac{R_{S,t-1}}{\pi_t} - \frac{\varepsilon_{E,t} + \varepsilon_{S,t}}{\pi_t} \right] + (1-\gamma) (1-\rho_D) \left[ (1-\rho_D) \left( l_{E,t} + l_{S,t} - \varepsilon_t \left[ \epsilon_{E,t} + \epsilon_{S,t} \right] \right) \right],
\]

From equation (7a), the expenditure side of the banker is given by consumption, repayment of deposit liabilities \(\frac{R_{H,t-1}}{\pi_t} d_{t-1}\), loans extended to both impatient households and entrepreneurs and also the resources necessary to pay the costs related to the management of the banker’s portfolio of deposits, loans to entrepreneurs,

\(^5\)Notice that in this model there is no maturity transformation, as debt is refinanced each period.
and loans to the impatient household. On the income side, the banker issues debt in the form of deposit liabilities, receives the gross repayment of mortgages extended to both entrepreneurs and household borrowers and suffers stochastic losses on its loans given that can originate in the entrepreneurial sector ($\epsilon_{E,t}$) or in the household sector ($\epsilon_{H,t}$). I shall analyse the macroeconomic implications of these two shocks later in the paper. The parameter $\gamma_t$ in (7b) denotes capital adequacy constraint that restricts bank leverage. Although in Gersbach and Rochet (2017) deposit investors’ participation constraint can affect the ability of the bank to raise deposits by imposing what they term a market-imposed solvency ratio, these authors and Van den Heuvel (2008) conceive of bank capital as also arising from regulatory concerns. Indeed, in this model $\gamma$ is time-varying and banks are required to meet the following expected-loss-adjusted time-varying capital-to-asset constraint:

$$
\frac{l_t - d_t - \mathbb{E}_t[D_{t+1}]}{l_t - \mathbb{E}_t[C_{t+1}]} \geq 1 - \gamma_t.
$$

The formulation in (7b) simply adds some inertia to the leverage constraint in (8) to allow for slow dynamics in corrective adjustment. Equation 8 also affords a more familiar representation, which resembles a collateral constraint

$$
d_t \leq \gamma_t (l_t - \mathbb{E}_t[C_{t+1}]).
$$

In words, the banker can issue deposit liabilities only in proportion to value of the loss-adjusted portfolio of loans it can collateralise.

3.4. Entrepreneur

The entrepreneur produces intermediate goods and sells them wholesale to the retail sector at a competitive price $P^w$ that equals the nominal marginal cost of production. They hire capital from patient households at the rental rate $R_{M,t}$ and labour from both households on competitive markets. Entrepreneurs also accumulate their own physical capital $K_{E,t}$, with utilization rate $z_{KE,t}$. Commercial real estate $H_{E,t}$ is not only a productive factor, but it also serves as collateral to obtain loans from banks. They choose paths of their choice variables $\{C_{E,t}, l_{E,t}, H_{E,t}, K_{E,t}, K_{H,t}, z_{KE,t}, N_{H,t}, N_{S,t}\}_{t=0}^{\infty}$ to maximize utility

$$
\mathbb{E}_t \left\{ \sum_{i=0}^{\infty} \frac{\rho_t^i (1 - \eta) \log (C_{E,t+i} - \eta C_{E,t+i-1})}{\pi_t} \right\}
$$

subject to a sequence of budget constraints and borrowing constraints, as expressed in real terms

$$
C_{E,t} + \frac{K_{E,t}}{A_{K,t}} + q_t (H_{E,t} - H_{E,t-1}) + \frac{R_{E,t}}{\pi_t} l_{E,t-1} + w_{H,t} N_{H,t} + w_{S,t} N_{S,t} + R_{M,t} z_{KH,t} K_{H,t-1} + \alpha c_{KE,t} + \alpha c_{KE,t}
$$

$$
\frac{Y_t^w}{X_t} = \frac{1 - \delta_{KE,t}}{A_{K,t}} K_{E,t-1} + l_{E,t} + \epsilon_{E,t},
$$

$$
l_{E,t} \leq \rho_t \frac{l_{E,t-1}}{\pi_t} + (1 - \rho_t) A_{KE,t} \left( m_{H,t} E_t \left[ \frac{q_{t+1}\pi_{t+1}}{R_{E,t+1}} H_{E,t} \right] + m_{K,t} K_{E,t} - m_{N,t} \left( w_{H,t} N_{H,t} + w_{S,t} N_{S,t} \right) \right)
$$

$$
Y_t^w = A_{Z,t} \left[ z_{KH,t} K_{H,t-1} \right]^{(1 - \mu)} \left( z_{KE,t} K_{E,t-1} \right)^{\mu} H_{E,t-1}^{(1 - \alpha - \nu)(1 - \sigma)} N_{S,t-1}^{(1 - \alpha - \nu)\sigma}
$$

The period budget constraint in equation (11) imposes that the entrepreneur consume, accumulate capital and real estate, service debt, pay wage bills, rental costs of household capital, and costs to the adjustment of their capital stock and portfolio of loans, commensurate to the real revenues form production, the undepreciated fraction of capital from the previous period, the market value of their stock of real estate from the previous period.
period, and the amount of loans obtained from the bank. If the entrepreneur repudiates its mortgage at time $t$, they will also receive a transfer shock from the equity of the bank in the amount $\varepsilon E_t$. Similarly to the banker and the impatient household, they face a binding collateral constraint (12), such that they can borrow only up to a specific fraction $m H_t E_t \left[ q_{t+1} \pi_{t+1} R_{E,t+1} H_{E,t} \right]$ of the expected value of their stock of commercial real estate net of the fraction of the total wage bill and own capital stock that they need to operate their technology. The production function given in Equation 13 features constant returns to scale and mixes capital services supplied by the household savers with the entrepreneur’s own capital services and commercial real estate. Moreover, the entrepreneur hires labour from both households.

### 3.5. Retailers and Price Setting

In order to motivate sticky aggregate prices, I introduce a monopolistic competition in the retail sector.$^6$ Each retailer operates as a monopolist over a segment of the market for final goods, and is price-taker in the market for intermediate goods. The marginal cost of production for the retailer is simply the cost of the intermediate good they buy from the entrepreneurs, as there are no costs to product differentiation. Retailers sell their final goods at a mark-up over their marginal cost and rebate their profits lump-sum to the patient households, who own the retail firm.

There exists a continuum of retailers indexed $j \in [0,1]$. Each retailer $j$ produces quantity $Y_t(j)$ of output, which they sell at the nominal price $P_t(j)$. The continuum of retail goods is bundled into a CES total production index

$$Y_t = \left( \int_0^1 Y_t(j)^{\frac{1}{\epsilon}} d j \right)^{\frac{\epsilon}{\epsilon-1}} \tag{14}$$

Each retailer maximizes profits

$$\max_{Y_t(j)} P_t \left( \int_0^1 Y_t(j)^{\frac{1}{\epsilon}} d j \right)^{\frac{\epsilon}{\epsilon-1}} - \int_0^1 P_t(j) Y_t(j) d j \tag{15}$$

whose first-order condition yields a sequence of downward-sloping demand schedules

$$Y_t(j) = \left( \frac{P_t(j)}{P_t} \right)^{\frac{1}{\epsilon}} Y_t \tag{16}$$

From cost minimization by users of the final good, the aggregate consumer-price index is

$$P_{t}^{1-\epsilon} = \int_0^1 P_t(j)^{1-\epsilon} d j \tag{17}$$

Each period, only a stochastic fraction $1-\theta$ of retailers is allowed to reset prices optimally (Calvo, 1983). Since opportunities to reset the price are independently distributed, each retailer in the continuum who resets the price optimally at time $t$ must factor in their discounting of future profits the probability $\theta^i$ that by time $t+i$ they might not be able to reset their price optimally:

$$\max_{P_t(j)} \mathbb{E}_t \left\{ \sum_{i=0}^{\infty} \theta^i \mathbb{M}_{t+i} \left( \frac{P_t^*(j)}{P_{t+i}^*} Y_{t+i}^*(j) - \frac{P_{t+i}^*}{P_{t+i} Y_{t+i}^*} \right) \right\} \tag{18}$$

$^6$In their seminal contribution to the New Keynesian debate on price stickiness, Kehoe and Midrigan (2015) analyse micro-price data contained in the CPI Research Dataset developed by the U.S. Bureau of Labor Statistics and identify models that are consistent with their observations: although they observe high-frequency price flexibility, these changes are very transient, with prices returning quickly to their mode, or regular price, which in turn changes infrequently over time. The implied stickiness in aggregate prices is substantial and consistent with both menu costs models and the Calvo mechanism, albeit the latter captures these features of the data only in a reduced form way.
where \( \mathcal{M} \) is the pricing kernel of the patient household, namely \( \mathcal{M} = \beta \frac{U'(C_{H,t+1})}{U'(C_{H,t})} \). If the reset price of a retailer \( j \) at \( t \) is \( P_{t}^{*}(j) \), the demand schedule they will face at \( t + i \) if they have not received the signal to change price by that time will be

\[
Y_{t+i}^{*}(j) = \left( \frac{P_{t}^{*}(j)}{P_{t+i}} \right)^{-\gamma} Y_{t+i}
\]

(19)

In Appendix B I provide a full derivation of the optimization problem faced by retailer \( j \) with the addition of dynamic price indexation.

### 3.6. Central Bank

The central bank implements a baseline Taylor rule that responds to deviations of the gross inflation rate from its steady state level of unity and to the growth rate of aggregate output (Fernández-Villaverde, 2010), but it can also decide to place a non-zero feedback coefficient on the growth rate of credit. If it does, monetary policy takes a leaning-against-the-wind stance

\[
R_{t} = \left( R_{t-1} \right)^{\rho R} \left[ \left( \frac{\pi_{t}}{\pi_{t-1}} \right)^{\phi R} \left( \frac{Y_{t}}{Y_{t-1}} \right)^{\gamma V} \left( \frac{l_{t}}{l_{t-1}} \right)^{\gamma LTV} \left( \frac{\gamma_{LTV}}{\gamma_{LTV}} \right)^{\gamma_{CCyR}} \right]^{1-\nu R}
\]

(20)

As standard, the central bank smooths the change in the nominal short-run rate by an autoregressive coefficient \( \phi_{R} \).

### 3.7. Prudential Regulator

I assume that the prudential regulator observes developments in macroeconomic aggregates which deemed to be the closest indicator for risk factors in the model, namely the volume of loans to the non-financial sector, but retains latitude for additional manoeuvre to take into consideration the state of economic activity. In this perspective, therefore, I assume that the regulator has a concern for stabilization. I introduce macroprudential policy by assuming that the regulator can steer each policy instrument by following the simple rule

\[
g_{j,t} = g_{j} \left( \frac{l_{t}}{l_{t-1}} \right)^{\omega_{LTV}} \left( \frac{Y_{t}}{Y_{t-1}} \right)^{\omega_{Y_{LTV}}} \left( \frac{Y_{CCyR}}{Y_{CCyR}} \right)^{\omega_{Y_{CCyR}}}, \quad g_{j,t} \in \{ m_{H,t}, m_{S,t}, m_{K,t}, \gamma_{S,t}, \gamma_{E,t} \}, \tag{21}
\]

such that

\[
m_{j,t} = m_{j} \left( \frac{l_{t}}{l_{t-1}} \right)^{\omega_{LTV}} \left( \frac{Y_{t}}{Y_{t-1}} \right)^{\omega_{Y_{LTV}}} \left( \frac{Y_{CCyR}}{Y_{CCyR}} \right)^{\omega_{Y_{CCyR}}}, \quad m_{j,t} \in \{ m_{H,t}, m_{S,t}, m_{K,t} \}, \tag{22}
\]

and

\[
\gamma_{j,t} = \gamma_{j} \left( \frac{l_{t}}{l_{t-1}} \right)^{\omega_{Y_{CCyR}}}, \quad \gamma_{j,t} \in \{ \gamma_{S,t}, \gamma_{E,t} \}. \tag{23}
\]

Coefficients \( \omega_{LTV} \) and \( \omega_{Y_{CCyR}} \) quantify the response of the regulator to variation in credit growth, while \( \omega_{Y_{LTV}} \) and \( \omega_{Y_{CCyR}} \) represent the adjustment to output growth in the maximum LTV and countercyclical capital buffer rules, respectively. For simplicity, I assume that the reaction of the regulator must be homogeneous across instruments within a class, such that, for example, all LTV ratios must adjust by \( \omega_{LTV} \), with no differential adjustment allowed.

In essence, in the face of a credit boom the prudential regulator takes immediate action both on the demand and on the supply side of the credit market by means of a rich set of instruments.\(^7\) On the demand side, the

\(^7\) Notice that I posit the absence of smoothing in the simple rule followed by the regulator. I motivate this choice by the presence of considerable inertia in the collateral constraints of all agents (see the calibration section), which per se dampens the effects of the policy intervention. In the absence of a clear prior, modelling additional inertia in the policy rule on the grounds of an uncertainty motive appears unnecessary for the case at hand. Also Tayler and Zilberman (2016) and Gelain and Ilbas (2017) do not find support for specifications that include smoothing.
regulator reacts by lowering LTVs, namely requiring that purchases of housing and capital be sustained by higher internal finance, thereby forcing the borrower to draw on more of their equity than before the intervention to access a loan of the same nominal value. As far as the dynamics of the model are concerned, the regulator limits the incentive of household to leverage by tightening their borrowing constraint in the credit market upturn and relaxing it as the credit cycle reverses.

On the supply side, the regulator lowers γ for entrepreneurs and household borrowers in order to maintain commercial bank capital sufficiently high through the positive credit fluctuation and ensure enough liquidity in the banking sector in case an adverse shock eats into the balance sheet of the banker or affect the riskiness of their assets. Holding the banker’s impatience constant, the regulator acts on the marginal propensity of the bankers to delever. In the expansionary phase of the credit cycle, the regulator lowers γ, in turn, forces the bank to increase the rate it requires from entrepreneurs so as to smooth consumption in compensation of the tightening of the collateral constraint. The resulting reduction in credit origination decreases entrepreneurial borrowing for a given market value of collateralizable real estate.

On the contrary, in the contractionary phase, when the balance sheet of the bank is damaged by asset write-downs and charge-offs, the regulator increases γ, namely decreases the capital requirement ratio. This adjustment increases the liquidity value of loans as means to raise deposits from patient households. Put differently, the improvement in the collateralizability of the banker’s assets afforded by the policy intervention decreases their incentive to delever by crunching credit and engaging in fire sales. In this perspective, credit spreads remain low and closer to their equilibrium level. I assume full compliance to regulatory standards⁸.

3.8. Aggregation and Equilibrium

Equilibrium in the goods market requires that

\[ Y_t = C_H + C_S + C_B + C_E + K_{H,t} - (1 - \delta_{KH,t})K_{H,t-1} + K_{E,t} - (1 - \delta_{KE,t})K_{E,t-1} = C_l + I_t \] (24)

and, as in the standard result by Yun (1996), there is a deadweight loss of intermediate output due to price dispersion. This is apparent by noting that, using the downward-sloping demand schedule faced by each retailer \( j \), the transformation of intermediate output into aggregate final output is

\[ Y^w_t = \int_0^1 Y_t(j) d j = Y_t \int_0^1 \left( \frac{P_t(j)}{P_t} \right) d j \] (25)

Denoting \( h_{3,t} = \int_0^1 \left( \frac{P_t(j)}{P_t} \right) d j \), it follows that

\[ Y_t = \frac{A_{Z,t} \left( z_{KH,t}, K_{H,t-1} \right)^{1-\mu} \left( z_{KE,t} K_{E,t-1} \right)^{1-\mu} H_{E,t-1} H_{E,t} N_{H,t} N_{H,t} N_{S,t} N_{S,t}}{h_{3,t}} \]

\[ = Y^w_t h_{3,t} \] (26)

where \( Y_t \) is the aggregate production index and \( h_{3,t} \geq 1 \) is a measure of price dispersion. Adjusting for price dispersion, profits must equal

\[ \Pi_t = \left( \frac{1}{h_{3,t}} - \frac{1}{X_t} \right) Y^w_t \]

\[ = Y_t - \frac{Y^w_t}{X_t}. \] (27)

⁸Bengui and Bianchi (2018) develop a model where there is only partial compliance to macroprudential taxes on debt. Their analysis of optimal macroprudential policy suggests that the effectiveness of macroprudential policy vis-à-vis weak enforcement remains substantial both in terms of agents’ welfare and probability of a financial crisis.
The evolution of inflation is described by

$$\pi_t^{1-\epsilon} = (1 - \theta) (\pi_t^*)^{1-\epsilon} + \theta (\pi_{t-1})^{1-\epsilon}$$

(28)

where $\chi$ is the degree of dynamic price indexation. Market-clearing in the market for real estate, where units of real estate are in fixed supply, implies

$$H_{H,t} + H_{S,t} + H_{E,t} = 1.$$  

(29)

In the credit market, where all funds are intermediated by commercial banks, the borrowing constraint of the bank defines the volume of loans in the economy

$$d_t \leq \rho_d \left( \frac{d_{t-1}}{\pi_t} - \frac{l_{E,t-1}}{\pi_t} + \frac{l_{S,t-1}}{\pi_t} - E_{t-1} \left[ \epsilon_{E,t} + \epsilon_{S,t} \right] \right) + \left( 1 - (1 - \gamma_d) \left( 1 - \rho_d \right) \left( l_{E,t} + l_{S,t} - E_t \left[ \epsilon_{E,t} + \epsilon_{H,t+1} \right] \right) \right)$$

(30)

4. Calibration

I perform a quarterly calibration of the model, solve it by taking a first-order approximation to the policy and transition functions around the non-stochastic steady state, and simulate it over 2000 periods. Table 1 presents the calibrated values of the parameters in the model. I calibrate most of the parameters in the model to their posterior mean estimated by Iacoviello (2015) to matching key moments in the U.S. economy. The relative utility weight of leisure in the preference is calibrated to 2 so as to pin down a share of labour time of 0.5. The inverse of the labour supply elasticity is calibrated to unity, a value that seems approximately consistent with the literature on liquidity constraints (Domeij and Flodén, 2006), according to which microeconometric estimates of the labour supply elasticity can be biased by as much as 50 percent.

As far as monetary policy is concerned, I set up a simple symmetric exercise by which, when augmented with a response to credit growth, the simple policy rule responds with a coefficient that is identical to that on output growth (0.12).

5. Transmission Mechanisms

In this section, I provide a description of the mechanisms underlying the propagation of the shocks I feed into the model. First, I present the workings of a standard technology shock, which provides a conveniently familiar setting and sets the stage to a more thorough appraisal of the dynamics involved in the subsequent two shocks, namely mortgage default shocks. These two financial shocks are calibrated to generate similar effects as those represented in Figure 2, since they proxy a sudden rise in the amount of loan charge-offs listed in the balance sheet of the bank. There are no deadweight default costs associated with a mortgage shock, such that no wealth is lost, but simply redistributed from the banker to the defaulting mortgagor. The difference between the two shocks lies in their origin. In the first shock, household borrowers default on their loans, while in second shock entrepreneurs default on their business loans. As I shall explain, this difference bears important consequences for monetary policy. In Figures 4 to 6 the green dashed line represents the baseline real business cycle version of the model, in which prices are perfectly flexible; the red solid line corresponds to the path of the endogenous variables implied by a central bank following a standard flexible inflation-targeting Taylor rule; the blue dashed line corresponds to the Taylor rule augmented with a response to credit growth.

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9This is because it is possible to rewrite $P_t^{1-\epsilon} = \int_0^{1-\epsilon} \pi_t^* d\eta + \int_0^{1-\epsilon} \pi_t^{(1-\epsilon)} P_{t-1} (j)^{1-\epsilon} d\eta$ since it is possible to separate the unit interval into subintervals proportional to one another on account of the stochasticity of price changes and the countable infinity of retailers. It follows that, by intergrating out, $P_t^{1-\epsilon} = (1 - \theta) P_t^{1-\epsilon} + \pi_t^{(1-\epsilon)} \delta P_{t-1}^{1-\epsilon}$. Dividing through by $P_{t-1}^{1-\epsilon}$ yields the expression in the text.

10For simplicity, I there is zero net inflation at the non-stochastic state and disregard trend inflation. For an in-depth analysis of the perils and modelling costs related to such an approximation, see Ascari and Sbordone (2014).
5.1. Technology shock

In the first instance, I present the response of the economy to a shock that raises total factor productivity, and therefore affects supply by pushing output and inflation in opposite directions. On the production side,
the increase in productivity lowers real marginal costs, thereby increasing the mark-up on final goods. By the same token, the increase in output undershoots the increase in the counterfactual flexible-price level of output, and therefore a negative output gap opens up. By the New Keynesian Phillips curve relationship, for a given level of price stickiness, a positive (negative) mark-up gap (output gap) generates downward pressure on prices. On the demand side, all agents increase their consumption. Notice that since profits are increasing in the mark-up, patient households consume nearly as much as under flexible prices. In view of increased demand for housing on the part of entrepreneurs and household borrowers, they also sell part of their housing stock at the now higher price. Quickly escalating house prices inflate collateral and fuel credit demand. Banks can now collateralize a larger portfolio of loans, which allows them to issue more deposit liabilities and transform them into loanable funds.

Figure 4: Impulse Response Functions to a Positive Technology Shock (Positive Supply Shock)

Notes: Time on the x-axis is measured in quarters of a year. The deviation from the non-stochastic steady state is measured in percentage on the y-axis. The time series in the graph originate from 2000 simulations.

Furthermore, the dynamic responses plotted in Figure 4 afford to gain valuable intuition on the effects of LAW monetary policy, and the implied trade-offs, through expected inflation and borrowing constraints.
When monetary policy reacts to the positive growth in credit, lower inflation expectations increase the real interest rate by more than under the conventional monetary policy rule. Due to the financial amplification mechanisms of the model, movements in the financial sector are more persistent than movements in the real economy. Indeed, the implied real monetary tightening maintains the volume of lending lower than that implied by the standard rule for a longer time than it keeps output from reaching the same level as implied by the standard rule. This can be rationalised by looking at the path of inflation. Low expected inflation acts on the balance sheet of borrowers through two channels. On the one hand, it makes the real burden of debt service heavier through higher real interest rates, and on the other hand, it shrinks the value of their collateral, which impairs their creditworthiness.

In summary, the lower induced credit growth has the usual static first-order effect of lowering aggregate demand at the time of the shock, which feeds into a lower expected inflation rate. Low inflation expectations, in turn, acts dynamically to further depress the value of collateral, which puts even more downward pressure on credit growth and inflation. Credit growth can be contained for long, but only if the central bank accepts an inflation rate that falls below target by more in the short run and remains low for a comparatively long period of time.

5.2. Mortgage Default Shock: Impatient Household

A mortgage default shock represents a damage to the balance sheet of the bank, and the dynamic responses it generates are depicted in Figure 5. In this case, the redistributive shock favours impatient households, who divert to private spending the fraction of income they would have forgone to repay their mortgage had they not repudiated their mortgage debt. Notice that in the absence of a credit-dependent entrepreneurial sector, the redistributive shock to the impatient household would be akin to a positive aggregate demand shock.

To understand the workings of this financial shock, imagine to recast the model in a setting without credit-dependent entrepreneurs and substitute them for a prototypical competitive wholesale firm owned by patient households, whose technology features labour as sole input in production. Leveraged banks intermediate funds from household savers to household borrowers. Further assume that the interest rate on the loans extended to household borrowers is not pre-determined.

As the shock hits, the sudden availability of funds to the impatient household would reduce the labour supply of its members, who now would want to consume more. However, while the shock relaxes the bite of the borrowing constraint for household borrowers, it simultaneously makes the capital adequacy constraint bite tighter, because the losses on household mortgages suffered by the bank have reduced its net worth. The sudden incapacity of the bank to issue debt makes deposit supply fall. Incapable of smoothing consumption by means of borrowing, the banker must therefore curb household loans. Crucially, however, the mortgage default shock lowers the demand for loans on the part of household borrowers, reducing equilibrium borrowing and increasing the lending rate. Notice that for a reasonable shock size, the increase in lending rate more than offsets the fall in borrowing capacity of the banker, leading the banker to consume more. In summary, in this minimal model the default shock neutralizes the credit crunch and increases aggregate demand. Lower employment increases equilibrium marginal costs, raising inflation at the same time as output increases.

This is not the case in the general model at hand, where the only rate that is not pre-determined is the interest rate on entrepreneurial loans. In this setting, the equilibrium lending rate would not increase if the bank did not curtail the supply of business loans, as loans are always in demand on the part of the entrepreneur, for whom the collateral constraint is always binding. Hence, the effect on inflation and on impatient households remains as outlined in the minimal model, but now it is accompanied by a fall in aggregate output due to the recapitalization effort of the bank at the expense of productive credit origination. Indeed, due to the complementarity in production between labor and capital services, the decline in hours supplied by both households is also matched by a reduction in the intensity with which the entrepreneur utilises both strands of capital.

This adjustment translates into a lower marginal product of the technology taken as whole, once total factor productivity is adjusted by the utilization rate. Hence, the now higher marginal cost of production creates upward pressure on inflation.

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11It is not necessary for the banker to increase consumption for the net effect on aggregate demand to be positive.
As it appears, also this shock creates a nontrivial policy trade-off for a central bank concerned with both price and financial stability: the real expansion generated by leaning against the wind prevents an even larger output dip, cushioning the fall in bank capital, yet it comes at the cost of higher inflation than under the conventional Taylor rule.

Figure 5: Impulse Response Functions to a Mortgage Default Shock: Impatient Household (Redistributive Financial Shock)

5.3. Mortgage Default Shock: Entrepreneur

This mortgage default shock redistributes wealth from the books of the bank to the entrepreneur’s, and its dynamic effects are presented in Figure 6. In this case, the default decreases the multiplier on the collateral constraint of the entrepreneurs, reducing their borrowing needs and consequently increasing the interest rate on business loans. The new equilibrium lending rate partly compensates the banker for the deterioration of their balance sheet caused by the mortgage default, thereby mitigating the credit cycle. However, its consequences for the macroeconomy in the presence of sticky prices are more subtle than in the previous case.
To see this, notice that formally, by relaxing the collateral constraint of the entrepreneur, the shock reduces their marginal utility of consumption, consequently increasing Tobin’s (marginal) Q, namely the marginal value of additional capital in units of consumption. This raises the incentive for the entrepreneur to invest. On the other hand, the redistributive shock effectively induces an adjustment in the relative demand for housing and consumption, because it transfers wealth from an agent who consumes only (the banker), to another who must choose between consuming and accumulating real estate for the purpose of production (the entrepreneur). However, the presence of sticky prices drives a wedge between the two demands. Indeed, under flexible prices, house prices would adjust upward one-for-one with the fall in the price of consumption goods, which means that in substituting away from housing in favour of consumption, the sale of an additional unit of real estate affords higher revenues in units of consumption than under sticky prices, where the fall in the price of consumption goods is dampened by nominal rigidities and therefore holds back the rise in house prices considerably. Indeed, real house prices barely rise in the presence of sticky prices. The implication is that the income side of the entrepreneur’s budget constraint shrinks relative to the case of flexible prices, which is equivalent to an increase in the shadow price of additional consumption, namely an increase in the marginal utility of consumption. Moreover, lower expected house prices and lower expected inflation shrink the expected value of collateral, against which both the entrepreneur and the impatient household borrow, and increase the real burden of debt service. Clearly, the bite of these effects is stronger on the impatient household, for whom the borrowing constraint remains binding in this case.

To sum up, the redistributive shock under sticky prices effectively triggers a race between higher marginal value of capital induced by the relaxation of the borrowing constraint generated by the shock as opposed to lower current revenue from the sale of real estate and lower expected collateral value. As the latter effects dominate, Tobin’s Q falls, such that the net effect on capital demand and investment is negative, accompanied by a fall in capital utilization and employment. Taken together, these dynamics imply that net of the effects induced by sticky prices, the shock generates a modest and short-lived downturn associated with a drop in inflation.

The policy implications of this shock stand in contrast with the results obtained in the previous two sections: when monetary policy leans against the wind, its action to counteract the drop in the volume of bank lending effectively stabilises credit, inflation, and output simultaneously. The dynamic responses to a positive housing demand shock depicted in D generate the same conclusion.

6. Optimal Policies

In his assessment of the design of central banks, Reis (2013) comments that the mandates of central banks, however enshrined in a legal framework, are usually vague. For the purpose at hand, the relevant source of vagueness is constituted by the concern for financial stability and whether it shall explicitly belong among the objectives of the central bank. To the extent that financial markets are characterised by frictions and prices are not completely flexible, financial instability affects the mechanisms of transmission of monetary policy, such that whether or not the central bank acts on the financial cycle, the financial cycle affects the outcomes of the central bank’s decisions regardless. Hence, one can conceive of a situation, as the one presented in Figure 6, in which leaning against the wind is the best response of the central bank given its other objectives and the economic circumstances it is confronted with. On these grounds, and throughout the remaining of the paper, I assume that the central bank derives a loss from the variability of credit growth, as an indicator of financial unbalance, and that, irrespective of whether it is mandated to, it can act on it by leaning against the wind.

In the following two subsections, I solve the optimization problems of monetary and macroprudential policies, subject to the constraints imposed by the competitive equilibrium of the economy. In the first subsection, the two policymakers implement optimal simple policy rules to minimize their respective loss functions. Such rules are attractive for the study of optimal policy, because they provide a reasonably good representation of the way policy is conducted while they remain parsimonious and tractable from a modelling perspective. In the second subsection, the objective of policy is to maximize the expected value of social welfare. Clearly, while there exists no legal framework that explicitly mandates central banks to adopt policies that maximize social welfare, welfare evaluation provides a microfoundation to the search for optimal policy.
To compute optimal policies, I solve and simulate the model at second order for each combination of policy coefficients and grid-search the policy coefficient space over $\phi_r \in [1, 4]$ with steps of 0.1, $\phi_Y \in [0, 1]$ with steps of 0.01 for monetary policy, while for macroprudential policy $\phi_{LTV} \in [-4, 0]$ with steps of 0.2, $\phi_{YLTV} \in [-1, 0]$ with steps of 0.05, $\phi_{CCyR} \in [-4, 0]$ with steps of 0.2, and $\phi_{YCCyR} \in [-1, 0]$ with steps of 0.05. Only the weight on output growth changes across columns of the tables, while the other weights are kept fixed at: $\lambda_{RMP} = 0.025$, $\lambda_{MP} = 0.25$, $\lambda_{MP} = 0.0625$ for monetary policy, and $\lambda_{MPP} = 0.025$. Consideration of larger values of the coefficients would not only make the computational intensity of the exercise even more cumbersome, but also lead to unrealistic policy specifications, a point that is shared with Schmitt-Grohé and Uribe (2006)\(^{12}\).\(^{12}\)

\(^{12}\)It shall be noted that, similarly to many other papers in the literature, in the following two analyses I disregard the probability...
6.1. Loss Functions

I follow De Paoli and Paustian (2017), Ferrero et al. (2018) and envisage a dynamic non-cooperative game between the two policymakers. In particular, I assume that the prudential authority acts as Stackelberg leader: it takes the benchmark calibration of the flexible inflation-targeting monetary policy rule as given and optimizes the macroprudential rule so as to minimize its own loss function. The monetary authority acts as follower: it takes the optimized macroprudential rule as given, and optimizes the coefficients of the Taylor rule so as to minimize its own loss function. This arrangement of the game provides an empirically sensible framework if one considers that macroprudential policy decisions are usually taken at lower frequency than monetary policy decisions, a reflection of the relatively lower frequency of the credit cycle with respect to the business cycle.

As in Svensson (2002), I assume that a monetary authority that pursues flexible inflation targeting adopts a quadratic intertemporal loss function of the form

$$L_{MP,t} = (1 - \beta_{MP}) \mathbb{E}_t \left\{ \sum_{i=1}^{\infty} \beta_{MP}^i L_{t+i} \right\}$$  (31)

where $\beta_{MP}$ is the discount factor of the central bank and $(1 - \beta_{MP})$ is a shift term. The associated sequence of period loss functions is

$$L_{MP,t} = \frac{1}{2} \left( (\pi_t - \pi)^2 + \lambda Z_{MP}^2 \right)$$  (32)

where $\pi$ is the inflation target and $Z$ is some target measure of economic slack. As observed in Svensson (2002), it is reasonable to assume that when the relevant period of time is a quarter of year, the discount factor approaches unity. This implies the limiting intertemporal loss function

$$\lim_{\beta_{MP} \to 1} L_{MP,t} = \frac{1}{2} \left( \sigma_\pi^2 + \lambda Z_{MP}^2 \right)$$  (33)

where $\sigma_\pi^2$ and $\sigma_Z^2$ are the unconditional variances of inflation and the target measure of economic slack. On these premises, I model the minimization problem of the monetary and prudential authorities by formulating loss functions augmented with financial variables and penalty terms associated with the volatility of their respective instruments. The central bank has the official simple mandate to minimize the variance of inflation and output growth, but it is also concerned also with the vairability of the interest rate and credit growth.

Woodford (2012) comments that a loss function augmented with a financial term (in his case, the ‘marginal crisis risk’) represents a ‘natural extension of inflation targeting’. Under the maintained assumption that credit growth is undesirable because it is a correlate of unobserved underlying sources of financial crises, Woodford’s interpretation applies to (34). As noted by Gelain and Ilbas (2017), the preferences of the prudential regulator are more challenging because there is no clear established benchmark. I follow Angelini et al. (2014) and assume that the prudential authority dislikes variance in credit and output growth. Angelini et al. (2014) use a single instrument (the countercyclical capital requirement), but in the model at hand the regulator can use 5 instruments. In order to approximate a penalty term that is symmetrical to the penalty on interest rate volatility in the loss function of the central bank, I impose a penalty that is proportional to the sum of the

$$L_{MP,t} = (1 - \beta_{MP}) \mathbb{E}_t \left\{ \sum_{i=0}^{\infty} \beta_{MP}^i \left( (\pi_{t+i} - \pi)^2 + \lambda_{MP}(Y_{t+i} - Y_{t+i-1})^2 + \lambda_{MP}^R(R_{t+i})^2 + \lambda_{MP}^c(l_{t+i} - l_{t+i-1})^2 \right) \right\}$$  (34)

that the optimally chosen monetary policy rules will imply negative interest rates at any horizons, thereby violating the the binding constraint imposed by the zero lower bound of the interest rate. To maintain the analysis simple, I neglect the rules of thumb of imposing standard deviation non-negativity constraints on the steady-state nominal interest rate or raising the steady-state inflation target. A similar consideration applies to maximum LTV ratios and capital requirements in the macroprudential rule, as in (Lambertini et al., 2013).
volatilities of all macroprudential instruments. The volatilities of all five instruments carry equal weight in the sum.

\[ \mathcal{L}_{MPP,t} = (1 - \beta_{MPP}) \mathbb{E} \left\{ \sum_{i=0}^{\infty} \beta_{i,t} \left( (Y_{t+i} - Y_{t+i-1})^2 + \lambda_{Y,MP} Y_{t+i}^2 + \lambda_{Y,MP} \sum_{j=1}^{5} \gamma_{j,t} Y_{t+j}^2 \right) \right\} \]

As shown by Gelain and Ilbas (2017), the two policies can circumvent conflictual action by assigning a comparable weight on the variance of the output gap. I can proxy this arrangement in the present context as well, by assigning the same weight on the variance in output growth. In addition to this, I consider the recent results by Debortoli et al. (2019). They estimate two medium-scale models and compute optimal mandates for the central bank to investigate whether it is beneficial for central banks to assign a positive weight to some measure of economic activity in the loss function (they consider output gap, de-trended output, and output growth). In fact, their estimates not only suggest that this should be the case, but also that conventional values of this weight proposed in the literature are too small (Woodford (2003) suggested an annual weight of 0.048 on the output gap, Yellen (2012) implied a weight of 0.25). I implement the result by Gelain and Ilbas (2017) by imposing that the preferences of the two policymakers be identical as far as output growth is concerned, while I take stock of the analysis by Debortoli et al. (2019) by allowing for a similar comparison of weights in the policymakers’ loss function. I leave all other weights in the loss functions of both policymakers constant. I attempt to make the two loss functions as symmetrical as possible. Throughout, I calibrate the loss functions to include quarterly weights on the volatilities of interest. Importantly, I set the annual weight on the main objective of each policymaker to unity and consider relative weights on the other objectives. I set the annual weights on instrument variability \( \lambda_{R,MP} = \lambda_{E,MP} = 0.1 \) (=0.025 quarterly) and credit growth in the loss function of the monetary authority \( \lambda_{C,MP} = 0.25 \) (=0.0625 quarterly). I justify the choice of a conservatively high relative weight on credit growth, more than double the estimate of 0.12 suggested by Laureys et al. (2017), by the desire to study LAW monetary policy and macroprudential policy in a setting where the incentive to lean is ex ante strong and financial stability is an important element in the loss function of the bank.

The result of the optimization are shown in Tables 2 for macroprudential policy and 3 for monetary policy. ‘Only LAW’ denotes a setting in which macroprudential policy is inactive and the central bank can lean against the wind, a proxy for the pre-GFC scenario, while ‘MPP leads, LAW MP follows’ denotes the dynamic game outlined before, in which monetary policy observes the optimal stance of macroprudential policy and plays its best response. Moving from left to right in the tables, I set an increasingly large weight on the output stability objective of the two authorities, in line with the results by Gelain and Ilbas (2017) and Debortoli et al. (2019). I consider quarterly values of the standard weights on output stabilization discussed in the literature, and therefore I set \( \lambda_{Y,MP} = 0.012 \) to pin down the annual weight of 0.048 proposed by Woodford (2003); \( \lambda_{Y,MP} = 0.0625 \) to pin down the annual weight of 0.25 implied in the statements by Yellen (2012), and finally a weight \( \lambda_{Y,MP} = 0.736 \) to pin down the annual weight of 2.943 proposed by Debortoli et al. (2019)\(^{13}\). Also the latter authors consider these three values in their analysis of the weight on output growth\(^{14}\).

Several important patterns appear: first, the table shows that the introduction of macroprudential policy reduces losses for the central bank independently of the shock under consideration. Second, the gains are increasing in the weight assigned to output growth only for the case of the entrepreneur’s shock, while are decreasing in the case of the technology and impatient’s shock. Third, there are no instances in which the price stability objective of the central bank is negatively affected. The aggressiveness towards inflation increases after the introduction of macroprudential policy when the impatient’s shock hits, and the same applies, albeit to a lesser extent, for the technology shock. This should not be misconstrued as a direct effect

\(^{13}\)Gelain and Ilbas (2017) suggest an optimal annual weight of \( \lambda_{Y,MP} = 0.55 \), a value that lies within the large range I test.

\(^{14}\)The true quarterly weight implied by Woodford (2003) is really 0.003, is a function of the deep parameters of his model (without capital), and refers to the output gap. Also the weight mentioned by Yellen (2012) refers to the output gap. However, my quarterly approximation of the annual weight suggested by Woodford (2003) still serves the purpose of providing a reasonably small weight on output for the case in which there is no output stabilization concern in my analysis.
of macroprudential policy on inflation. Rather, by moderating output fluctuations, macroprudential policy unburdens monetary policy of the need to respond to them and allows it to focus more on its inflation target. Fourth, notice how, as the weight on output increases, the coefficient on credit growth for the case with only monetary policy increases accordingly. The large gains in the loss function for the case of the entrepreneur’s shock associate with an increasing reduction of the need to lean against the wind as the weight on output growth increases and macroprudential policy is activated. For the optimized weight found by Debortoli et al. (2019), activating the full set of macroprudential instruments causes the coefficient on credit growth in the monetary policy rule to fall from 0.99 to 0.42. Fifth, the incentive to lean against the wind for the case of the case of technology and shock impatient’s shock moves opposite to the case in which the entrepreneur defaults. Absent macroprudential policy, $\rho_\omega$ diminishes as output grows in importance.

Taken together, the picture that emerges from the figures in the table is broadly consistent with the mechanisms of transmissions of the shocks described in the previous sections. For shocks that create a trade-off between output and inflation stabilization, increasing the weight of output in the loss function but holding the weight on inflation constant reduces the marginal value of an additional reduction in credit growth and output growth, while the positive effect on inflation of unburdening monetary policy of the stabilization objective appear to depend more on the financial or real nature of the shocks. Consistently with the findings by Angelini et al. (2014), the benefits from macroprudential policy are in fact higher in this respect when the financial shock appears to depend more on the financial or real nature of the shocks. Consistently with the findings by Angelini et al. (2014), the benefits from macroprudential policy are in fact higher in this respect when the financial shock appears to depend more on the financial or real nature of the shocks.

On the contrary, for a shock that creates no trade-off between output and inflation, the central bank would find it optimal to lean more in the absence of regulation, since that choice stabilizes output and credit at little cost. Sixth, there is a gain of larger magnitude if the shock is associated with a technological, while for bankers and entrepreneurs it is given by

$$W^p_{K,J} = \mathbb{E}_t \left\{ \sum_{i=0}^\infty \beta^i K U_K^p \left( C^p_{K,J+i} \right) \right\}, \quad K \in \{B,E\}.$$  

(37)

6.2. Welfare Analysis

In this section, I analyse optimal monetary and macroprudential policies from a welfare perspective, using the techniques derived by Schmitt-Grohé and Uribe (2004, 2006). For each specification of policy, I solve the model by taking a second-order approximation around the non-stochastic steady state, so as to allow for the unconditional expectation of welfare to vary across policy specifications, and then choose the one that maximizes society’s welfare. For reasons of consistency with the analysis of the loss functions, I take the case with no macroprudential regulation as the baseline policy and the case of optimal macroprudential regulation as the alternative policy.

Denote $p$ the state of policy in which no macroprudential regulation exists. The welfare of borrowers and savers is given by the expected discounted sum of future streams of utility

$$W^p_{J,t} = \mathbb{E}_t \left\{ \sum_{i=0}^\infty \beta^i J U_J^p \left( C^p_{J,J+i}, H^p_{J,J+i+1} \right) \right\}, \quad J \in \{H,S\}.$$  

(36)

while for bankers and entrepreneurs it is given by

$$W^p_{K,J} = \mathbb{E}_t \left\{ \sum_{i=0}^\infty \beta^i K U_K^p \left( C^p_{K,J+i} \right) \right\}, \quad K \in \{B,E\}.$$  

(37)
In this case monetary policy and macroprudential policy seek to maximize the stochastic (ergodic) mean of society's welfare, which is conveniently aggregated following Mendicino and Pescatori (2005)

\[ W_{society,t}^P = (1 - \beta_H) W_{H,t}^P + (1 - \beta_S) W_{S,t}^P + (1 - \beta_B) W_{B,t}^P + (1 - \beta_E) W_{E,t}^P \]  

This functional form proves convenient in view of the fact that since each agent carries a weight in the social welfare function that is proportional to their degree of patience, each agent will derive the same level of utility from the same flow of consumption. In order to derive a meaningful interpretation of the results, I express gains and losses of agents in terms of consumption equivalent (CE) variation, that is, the maximum fraction of consumption \( \xi \) that each agent would be willing to forgo in an economy in which macroprudential policy is inactive to join the economy in which macroprudential policy is active. Or, differently worded, the
amount of consumption each agent would require to be indifferent between staying in the economy without macroprudential policy and joining the economy with active macroprudential regulation. Formally, $\zeta$ must satisfy

$$E_t [W_t^P (\zeta)] = E_t \left\{ \sum_{i=0}^{\infty} \beta^i U \left( C_{t+i}^P (1 + \zeta), \cdot \right) \right\}$$

$$= E_t [W_t^{ap}] = E_t \left\{ \sum_{i=0}^{\infty} \beta^i U \left( C_{t+i}^{ap}, \cdot \right) \right\}$$

(39)

where the superscript $ap$ (alternative policy) denotes the state of policy in which macroprudential policy is active. Solving for $\zeta$ for each agent yields

$$\zeta = \exp \left( (1 - \beta) (E_t [W_t^{ap}] - E_t [W_t^P]) \right) - 1$$

(40)

It is apparent from Table 4 that, by construction, the model fails to make a welfare-relevant distinction between counter cyclical capital requirements and LAW monetary policy if both authorities can only respond with the same strength to shocks, as I have imposed, LTV caps are available, and banks are included in the computation of welfare.

Monetary policy actions affect directly the equilibrium nominal deposit rate, and therefore determine the liquidity conditions that are available to the banker, but also affect, at a second remove, the variability of consumption and housing for all agents in the model through the wealth effects inherent in the presence of non-indexed nominal debt in the model. On the other hand, countercyclical capital requirements undo the fluctuations in the availability of loanable funds through an offsetting mechanism that affects the lending rate on business loans, but does not alter the equilibrium that prevails in the market for deposits, as the deposit rate is completely outside the control of the bank and determined by the optimization problem of the patient household and the action of the central bank. So if the commercial bank cannot overborrow because of the aggressiveness of LAW and cannot over lend because of the aggressiveness of LTVs, that is the preferred course of action for macroprudential policy across all shocks, countercyclical capital requirements become redundant, and are therefore not favoured in the macroprudential rule.

Moreover, LTVs seem sufficient for optimal policy also for the case of the technology shock. It is important to remark that when macroprudential policy leads and monetary policy follows, the welfare-based optimized rule display generally better properties in terms of second moments than in the absence of optimized macroprudential policy, independently of the shock at hand.

Under all shocks, the stochastic average bank capital is higher due to the presence of the LTV, which means that bankers will have more consumption available.

For example, in the technology shock, the increase in factor productivity allows savers to shift investment to periods of high productivity, which raises the stochastic mean of their capital and consumption. Moreover lower inflation volatility reduces the volatility of the mark-up, ensuring higher stochastic retail profits. Entrepreneurs also produce capital and must substitute away from consumption to invest in highly productive periods. In view of their impatience this arrangement makes them worse off in terms of consumption variability, since they cannot smooth their consumption if the LTV bites tighter.

On the other hand, in the case of the entrepreneurs’ shock, the reduction in the volatility of aggregate borrowing caused by the introduction of active macroprudential policy reduces the savers’ gain, as they can no longer profit from the run down of the housing stock of entrepreneurs and impatient households. Not surprisingly, when this shock hits, the entrepreneur is least dissatisfied with this scenario than in the other cases, because they are the recipient of the windfall transfer, while the impatient household benefits from the smoother stream of consumption. With both financial shocks, little attention is paid by the central bank to inflation, which is beneficial to all borrowers as it allows their collateral constraint to relax.

In summary, as it is commonly found for welfare evaluation of models that feature financially constrained agents in the spirit of Lambertini et al. (2013), Rubio and Carrasco-Gallego (2014, 2016), albeit macroprudential policy is desirable for society under all three shocks, the aggregate picture masks the presence of winners and losers. Moreover, there is no single policy depicted in the table that makes all agents better off and none
worse off, which would represent a Pareto improvement. Nonetheless, a Kaldor-Hicks system of payments is conceivable in the case of the entrepreneur's shock, for example, whereby the impatient's household could redistribute part of the consumption equivalent variation to other agents who accrue no benefits from such a shock.

Finally, since entrepreneurs are always losers and bankers are always winners, in the three scenarios of the table, I recompute the values of expected welfare assuming that optimal monetary and macroprudential policies seek to maximise only welfare of the households (not shown), countercyclical requirements are incorporated anew in the toolkit of optimal macroprudential policy, but a more severe trade-off between borrowers' welfare and savers' welfare sets in, especially for the entrepreneur's shock.

### Table 4: Optimal Macropunlential Policy: Welfare Maximization

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Technology Shock</th>
<th>Entrepreneur</th>
<th>Impatient Household</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\omega_{LTV}$</td>
<td>-4.00</td>
<td>-4.00</td>
<td>-4.00</td>
</tr>
<tr>
<td>$\omega_{Y_{LTV}}$</td>
<td>-0.10</td>
<td>-1.00</td>
<td>-1.00</td>
</tr>
<tr>
<td>$\omega_{CC_{YR}}$</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>$\omega_{Y_{CC_{YR}}}$</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Notes: Grid search over $\omega_{LTV} \in [-4, 0]$ with steps of 0.2, $\omega_{Y_{LTV}} \in [-1, 0]$ with steps of 0.05, $\omega_{CC_{YR}} \in [-4, 0]$ with steps of 0.2, $\omega_{Y_{CC_{YR}}} \in [-1, 0]$ with steps of 0.05.

7. Sensitivity Analysis

7.1. Multishock Scenario

However instructive, the foregoing analysis featured conditioning sets made up of a single shock, either a technology shock, mortgage default shock on the part of impatient household, or a default shock on the part of entrepreneurs. It is evident that, although the second moments were computed by means of a second-order perturbation technique, assuming that there is only one shock in the conditioning set lacks realism, as typically agents and policymakers are confronted with a variety of shocks at the same time. Considering many shocks at the same time gives perspective on the costs and benefits of macroprudential policy in a highly volatile economy.

How would monetary and macroprudential policy play out in a multishock scenario? In order to investigate this question, I feed the full set of available shocks into the model at once and vary the weight on output growth in the loss functions of the two policy makers. This exploration is important because of a wealth of cross-derivative terms involved in the second-order perturbation as several shocks interact. An implication of the second-order perturbation is that, in view of the absence of certainty equivalence, it will cause the effect of the shocks to be state-dependent, as it will be dependent on the history of the economy when the shocks hit it. This is due to the fact that while in a linearised world the unconditional expectation of the variables in the rational expectations equilibrium equals their level in the non-stochastic steady state, at second order the variance of future shocks will affect the value of the policy functions.

All shocks are same-signed and positive, while the two redistributive shocks enter as positive equity shocks for the defaulting mortgagor and correspondingly negative equity shocks to the bank. The shocks under consideration are the 'animal spirits' preference shock to the demand for consumption and housing jointly, the housing preference shock, the shocks to borrowing standards on business and household loans, i.e. LTV shocks, the investment-specific technology shock, as well as the two redistributive shocks and the standard technology shock. Noticeably, the shock mix features mostly financial and preference shocks, which affords a suitable testing ground to judge the effectiveness of macroprudential policy. Table 6 presents the results of this exercise. The benefits of macroprudential policy are apparent. When monetary policy is confronted with all shocks at once and is concerned with credit growth, it takes an aggressive LAW stance irrespective on the weight on the output growth in the loss function. On the contrary, when the prudential regulator leads and the central bank takes the regulatory rule as given, the coefficient on credit growth in the Taylor rule
barely decreases for the case of $\lambda_{MP}^Y = \lambda_{MPP}^Y = 0.012$, but is lowered to zero for the other two cases, while the coefficients on inflation and output remain fixed at their upper bound.

Notably, it does not take a very aggressive optimal macroprudential response to address the multishock scenario given the baseline monetary policy rule. The responses to the financial variable in the macroprudential rules are comparable across instruments, although both the coefficient on output growth stabilization are slightly larger in the reaction of the countercyclical capital requirements for the lowest two weights on output growth in the loss function. At the maximum allowed weight on output both loadings on that variable in the macroprudential rule reach their lower bound. The prudential regulator finds it optimal to steer capital requirements and maximum loan-to-value ratios with similar intensity, which is suggestive of the degree of complementarity between the two, but also indicative of the fact that the impact of the shocks are likely to cancel out in such exercise, so that a balanced response is the best response of the macroprudential authority. By and large, the large decrease in the value of the loss function appears to be mostly driven by the conspicuous reduction in credit and output growth achieved by the use of all available macroprudential instruments at once. Notice that differently from the results obtained in 3, in this case most of the inflation cost deriving from the use of macroprudential policy is indirectly born by the reduced ability of monetary policy to direct its focus on price stability.

7.2. Volatility Frontiers

Optimal rules are essentially points in the volatility space of interest for the central bank. As such, they provide limited perspective on the whole opportunity set that the central bank faces subject to the constraints imposed by the competitive equilibrium. On this note, it is desirable to assess the impact of macroprudential policy at the margin. Indeed, it is sensible to believe that the presence of active macroprudential measures might not only affect optimal monetary policy conceived as a vector of coefficients that solve the minimization problem of the central bank, but also systematically reshape the portfolio of trade-offs available to the policymaker.

To understand whether this is actually the case, I consider the case of the household mortgage default shock, which, as seen in Section 5.2, is a financial shock that generates cost-push inflation. As discussed in Gertler et al. (1999), cost-push inflation must necessarily associate with a trade-off between output and inflation stabilization and sets the stage for meaningful policy insights. Can optimal macroprudential policy create a more favourable stabilization trade-off than leaning-against-the-wind monetary policy strategies? To answer this question, I proceed in two stages. First, I formulate two simple rules. In one rule, which I will refer to as ST rule, the central bank chooses only the coefficients on inflation and output growth, but cannot lean against the wind, namely the coefficient on credit growth is fixed to zero. Differently, the other rule, LAWT rule, is augmented with credit growth, so that the central bank can vary the loading on both responses to output and credit growth. For each rule I solve the model at second order for each parameterization of the rule, compute the implied unconditional second moments of interest such that each specification of policy maps onto a point in the volatility space, and take the envelope of all those points-policy specifications which, for each given value of the variance of inflation, offer the minimum variance of the other target variable, and contrariwise. This locus represents the efficient possibility set of monetary policy and embodies the menu of policy trade-offs available to the central bank. Lines that are closer to the origin are preferred.

In the second stage, I select the rule featuring the most attractive frontier and combine it with the optimized macroprudential policy rules computed in 2 for this shock. Figure 7 presents the results. First, ST rule features a more favourable output growth-inflation frontier, in line with the findings of Laureys et al. (2017), who study optimal monetary policy in an estimated model medium-scale DSGE model with frictions à la Gertler and Karadi (2011) and also find that financial stabilization on the part of monetary policy alone delivers a strictly dominated locus of volatility tuples in the inflation-output gap space. Second, ST rule is superior to LAWT rule as far as stabilization of credit growth is concerned, as one can verify by looking at the right hand-side panel of the figure.

This superior performance is not surprising in the light of the mechanisms that drive this shock, and confirm the intuition obtained in the linearised setting of Figure 5.

In the second stage, I take the best-performing rule, ST rule, and repeat the routine outlined before for each of the three optimal stances of macroprudential policy, each one corresponding to a different weight
on output growth stabilization in the loss function of the prudential regulator. Besides, in order to gain a
ballpark measure of how much the weight on output growth stabilization matters, I also combine ST rule
with a sub-optimal macroprudential rule, namely the rule that reflects minimizes the loss of the regulator
at $\lambda_{MPP}^Y = 0.0625$ but with coefficients on the output growth set to zero. This rule can be taken to loosely
proxy a moderately aggressive stance of macroprudential policy without an explicit concern for output growth
stabilization. By and large, the outcomes of these combinations emerge to produce more favourable frontiers
than when ST rule and macroprudential policy is inactive. The suboptimal rule not only performs worse than
its optimal counterpart, but also worse than the ‘light’ one ($\lambda_{MPP}^Y = 0.012$).

If anything, the implementation of macroprudential policy tilts the balance of the frontier towards output
growth, implying that once regulation is in place and the weight on output stabilization is high, a marginal
reduction in the variance of inflation offers a larger reduction in the variance of output growth then under
ST rule alone, while a marginal reduction in output growth costs more in terms of inflation variability. In
the right-hand side panel the aggressive macroprudential rule (black line) appears not only to improve upon
the other frontier, but also to reshape the frontier more in favour of inflation, such that lower credit growth
variability costs less in terms of higher variance of inflation that it is the case for the other frontiers. How-
ever, these changes in the shapes of the policy frontiers are extremely small and barely noticeable. All told,
macroprudential policy advantageously shifts the policy frontier closer to the origin, but preserves its shape.

Finally, two observations are noteworthy. For the left-hand side panel, I find that the output growth-
inflation stabilization trade-off is generally quite favourable, independently of the implemented rule, as op-
oposed to the case when the output gap is the relevant target variable. This is consistent with the output
growth-inflation frontier derived by Debortoli et al. (2019).

Conversely, the right-hand side panel features frontiers that are only mildly convex, when not almost flat:
irrespective of the presence of optimal macroprudential policy, reducing the variance of credit growth is a costly
task.\footnote{I also recompute the frontiers for the multishock scenario. Most of the observations in the main text carry over to this case.}

8. Conclusion

In the foregoing analysis I have considered the optimal conduct of monetary policy in response to both
real and financial shocks in an economy characterised by major financial market imperfections that can cause
severe financial instability. First, I have shown that in the presence of sticky prices mortgage defaults that
trigger credit cycles have different macroeconomic implications depending on their origin. When the mortgage
default shock originates in the household sector, the wealth effects it generates lead to cost-push inflation and
to an unfavourable trade-off between output and inflation stabilization. On the contrary, I find that mortgage
defaults on business loans cause a fall in output and inflation, even if they represent a positive shock to the
firms’ net worth.

Given the strong credit-supply and collateral channels embedded in the model, LAW actions pass through
to the financial market and successfully rein in credit growth. In this light, LAW is only effective at stabilizing
contemporaneously output, inflation and credit when output and inflation comove, but otherwise leads the
central bank to systematically miss its price stability objective in the short run.

Second, I act on this set of results to set up an optimization exercise to investigate whether monetary policy
should optimally lean against the wind or the task of financial stability is better delegated to macroprudential
policy alone. I embed in the model a prudential authority whose main concern is financial stability and
allow it to steer simultaneously 3 maximum loan-to-value ratios and 2 countercyclical capital requirements.
This exercise unveils that the gains from the use of a large number of macroprudential tools at the same
time are large and robust to different values of the weight on output growth in the loss function of the two
policymakers, and that, consistent with the empirical evidence by Funke et al. (2018) and Richter et al. (2019),
macroprudential policy does not affect price stability, independently of whether the shock creates a trade-off
between output and inflation stabilization. Moreover, optimal macroprudential completely eliminates the
need for monetary policy to lean against the wind for those shocks that create the trade-off.
Notes: Grid search over $\varphi_\pi \in [1.05, 4]$ with steps of 0.05 and all its combination with $\varphi_Y \in [0,1]$, with steps of 0.05, to obtain the standard Taylor rule $ST$ rule, and all its combination with $\varphi_Y \in [0,1]$, with steps of 0.05, and $\varphi_c \in [0,1]$, with steps of 0.05, to obtain the LAW Taylor rule $LAWT$ rule. Variances are multiplied by $10^6$. The coefficients for the macroprudential regimes are those in 2, in the columns relevant for the impatient household shock. To produce all curves where macroprudential policy is active, only the same $ST$ rule was used as that to produce the baseline red line, computed with inactive macroprudential policy. The case of ‘no stabilization concern’ is only partially optimal. It is produced by setting the coefficients on output growth to zero, but without allowing the regulator to re-optimize the remaining coefficients accordingly.

This is due to the fact that macroprudential policy allows monetary policy to shift concern from output stabilization to inflation stabilization. For shocks that do not create the trade-off, the desire of the monetary authority to lean against the wind in the absence of macroprudential policy increases with its concern for output, but that the desire to lean falls the more when macroprudential policy is in place, the higher the weight on output growth in the loss function. This suggests that monetary policy is always willing to substitute away from LAW in favour of optimal macroprudential policy, only that this willingness is decreasing in the weight on credit growth in the loss function of the central bank, since the near inexistence of a trade-off among the three target variable of LAW rules ultimately imposes negligible costs to leaning.

Thirdly, I assess welfare-based optimal monetary and macroprudential policies and find that the model cannot distinguish between capital requirements and LAW monetary policy when bankers are included in the social welfare function and aggressive LTVs cap rules are in place. In the case of mortgage default shocks, LAW actions can alone engineer an equilibrium rate in the deposit market such that, in combination with strongly countercyclical LTV caps, bankers remain capitalized, lend less, borrow less, and consume more. The general effect of the welfare-based rules is to generate positive welfare gains in the aggregate from the implementation of macroprudential policy, which nonetheless mask winners and loser, as it is often the case in models with heterogeneous agents. Across the range of shocks, borrowers never lose but savers under the entrepreneurs’ mortgage default shock do. Notably, the welfare-based rules take a very aggressive LAW stance as far as financial shocks are concerned, but less aggressive anti-inflationary stance, so that they allow borrowers to gain more than savers.

Fourth, I show that macroprudential policy completely eliminates the need for LAW in a realistic multi-shock setting for an annualised weight of 0.25 and above on output growth in the loss functions. This exercise
provides a robustness check that broadly confirms the results derived earlier.

Lastly, I show that for the cost-push shock imposed by the patient household mortgage default, the implementation of optimal macroprudential policies effectively shifts the efficient frontier of monetary policy to loci characterised by superior policy-trade-offs between and away from dominated curves, both in terms of output growth-inflation and credit growth-inflation trade-offs. However, macroprudential policy does not contribute to make the shape of the Taylor frontiers more favourable, providing only a positive ‘shift effect’.

By construction, my analysis is silent on the main key elements related to LAW that are discussed in the seminal contributions of, for example, Filardo and Rungcharoenkitkul (2016), Svensson (2017), Juselius et al. (2017): the ability of this strategy to consistently affect the probability of a crisis at the margin and to smooth the amplitude of the financial cycle, the probability of a binding ZLB, and many others. Moreover, it is possible to think of phases of the business cycle in which LAW imposes little to no cost, for instance when employment is well above its natural level and the policy rate would anyway be steered in a direction similar to that prescribed by LAW.

Evidently, while the methodological tools offered by a DSGE model allow to measure the effects of LAW in an asymptotic long-run by looking at asymptotic second moments, the probabilistic considerations and the subtle dynamic trade-offs that are ultimately relevant for a better assessment of LAW can hardly be captured in this framework. While my results suggest that financial stability concerns can be delegated to a macroprudential regulator acting on a number of instruments and that the regulator can mostly achieve financial stability objectives without imposing a cost in terms of price stability, they suggest that there is little support for the optimality of a monetary policy rule augmented with a positive coefficient on credit growth when optimized macroprudential policy is implemented, especially if shocks that create a non-trivial trade-off between stabilizing inflation and output are considered.

9. Acknowledgements

I am grateful to my advisor, Daria Finocchiaro, for her precious support and patience; Dmytro Stoyko and Benjamin Hemingway, for their exquisitely insightful comments at various stages in the preparation of this thesis; seminar participants at Uppsala University, whose suggestions are incorporated in the lines of this thesis, and lastly, I would like to express my sincere gratitude to the masters of the past, from Knut Wicksell to John M. Keynes, from James Tobin to Milton Friedman, and many other great economic minds, for their writings have ignited my passion for this superb discipline.

Disclaimer: I am the sole responsible for any errors and for the opinions expressed in this thesis.

References


Data Construction and Sources

Figure 1
The credit-to-GDP series is constructed by dividing total credit by nominal GDP. The credit-to-GDP gap is proxied by the difference between the actual series and the trend component of the series estimated by applying the Hamilton filter, i.e. the cyclical component of the series.

Total credit: Bank for International Settlements, Total Credit to Private Non-Financial Sector, Adjusted for Breaks, for United States [CRDQSUSAPABIS], retrieved from FRED, Federal Reserve Bank of St. Louis; (link to the series), March 27, 2019.

Nominal GDP: U.S. Bureau of Economic Analysis, Nominal Gross Domestic Product [GDP], retrieved from FRED, Federal Reserve Bank of St. Louis; (link to the series), March 27, 2019.

Real GDP: U.S. Bureau of Economic Analysis, Real Gross Domestic Product [GDPC1], retrieved from FRED, Federal Reserve Bank of St. Louis; (link to the series), March 27, 2019.

Real potential GDP: U.S. Bureau of Economic Analysis, Real Potential Gross Domestic Product [GDPPOT], retrieved from FRED, Federal Reserve Bank of St. Louis; (link to the series), March 27, 2019.

The real output gap is constructed by subtracting real potential GDP from actual real GDP.

Real house prices: OECD, Housing prices (indicator), retrieved from OECDiLibrary; (link to the series), March 27, 2019.

The real house price gap is proxied by the difference between the actual series and the trend component of the series estimated by applying the Hamilton filter; i.e. the cyclical component of the series.

Real house prices: OECD, Housing prices (indicator), retrieved from OECDiLibrary; (link to the series), March 27, 2019.

Figure 2
Leverage subindex: Federal Reserve Bank of Chicago, Chicago Fed National Financial Conditions Leverage Subindex [NFICLEVERAGE], retrieved from FRED, Federal Reserve Bank of St. Louis; (link to the series), June 3, 2019.

Credit subindex: Federal Reserve Bank of Chicago, Chicago Fed National Financial Conditions Credit Subindex [NFCICREDIT], retrieved from FRED, Federal Reserve Bank of St. Louis; (link to the series), June 3, 2019.


Charge-off rate (net of recoveries): Board of Governors of the Federal Reserve System (US), Charge-Off Rate on Loans Secured by Real Estate, All Commercial Banks [CORSREACBS], retrieved from FRED, Federal Reserve Bank of St. Louis; (link to the series), February 26, 2019.

Figure 3

Financial distress index: Federal Reserve Bank of St. Louis, St. Louis Fed Financial Stress Index [STLFSI], retrieved from FRED, Federal Reserve Bank of St. Louis; (link to the series), February 24, 2019.

Appendices

A. First-Order Conditions

The patient household chooses $C_{H,t}, K_{H,t}, z_{H,t}, d_t, H_{H,t}, N_{H,t}$:

$$A_{P,t}(1-\eta) \equiv u_{CH,t},$$

$$\frac{1}{A_{K,t}} u_{CH,t} \left[ 1 + \frac{\delta H_{K,t}}{\delta H_{t}} \right] = \beta H_{t} \left[ u_{CH,t+1} \left( R_{M,t+1} + \frac{1-\delta H_{K,t+1}}{A_{K,t+1}} \right) \right],$$

$$R_{M,t} = \frac{\delta H_{K,t}}{\delta H_{t}}$$

$$u_{CH,t} \left[ 1 + \frac{\delta C_{D,H,t}}{\delta d_t} \right] = \beta H_{t} \left[ u_{CH,t+1} \left( R_{H,t} \right) \right].$$

$$u_{CH,t} q_t = u_{HH,t} + \beta H_{t} \left[ u_{CH,t+1} q_{t+1} \right],$$

with $u_{HH,t} = \frac{H_{H,t}}{H_{H,t}}$.

$$u_{CH,t} w_{H,t} = \frac{C_{H,t}}{1 - N_{H,t}}.$$
The impatient household chooses $C_{S,t},H_{S,t},l_{S,t},N_{S,t}$:

$$A_R(1-\eta) = C_{S,t},$$

(A.2a)

$$u_{CS,t} \left[ q_{t} - \lambda_{S,t}(1-\rho_{S})m_{S,t}A_{MH,t}E_{t} \left( \frac{q_{t+1}^{1/\sigma_{t+1}}}{R_{S,t}} \right) \right] = u_{HS,t} + \beta_{S}E_{t} [u_{CS,t+1}q_{t+1}],$$

(A.2b)

$$u_{CS,t} \left[ 1 - \frac{\partial c_{SS,t}}{\partial S_{t}} - \lambda_{S,t} \right] = \beta_{S}E_{t} \left[ u_{CS,t+1} \left( \frac{R_{S,t}}{\pi_{t+1}} - \lambda_{S,t}q_{t+1}^{1/\sigma_{t+1}} \right) \right],$$

(A.2c)

$$u_{CS,t}w_{S,t} = \frac{\gamma_{t}}{1-N_{S,t}}.$$  

(A.2d)

The banker chooses $C_{B,t},d_{t},l_{E,t},l_{S,t}$:

$$\frac{(1-\eta)}{C_{B,t} - \gamma_{t}C_{B,t-1}} = u_{CB,t},$$

(A.3a)

$$u_{CB,t} \left[ 1 - \frac{\partial c_{DB,t}}{\partial D_{t}} - \lambda_{B,t} \right] = \beta_{B}E_{t} \left[ u_{CB,t+1} \left( \frac{R_{B,t}}{\pi_{t+1}} - \lambda_{B,t+1}q_{t+1}^{1/\sigma_{t+1}} \right) \right],$$

(A.3b)

$$u_{CB,t} \left[ 1 - \lambda_{B,t}(1-\rho) + \rho_{D} + \frac{\partial c_{EB,t}}{\partial E_{t}} \right] = \beta_{B}E_{t} \left[ u_{CB,t+1} \left( \frac{R_{B,t+1}}{\pi_{t+1}} - \lambda_{B,t+1}q_{t+1}^{1/\sigma_{t+1}} \right) \right],$$

(A.3c)

$$u_{CB,t} \left[ 1 - \lambda_{B,t}(1-\rho) + \rho_{D} + \frac{\partial c_{SB,t}}{\partial S_{t}} \right] = \beta_{B}E_{t} \left[ u_{CB,t+1} \left( \frac{R_{S,t}}{\pi_{t+1}} - \lambda_{B,t+1}q_{t+1}^{1/\sigma_{t+1}} \right) \right].$$

(A.3d)

The entrepreneur chooses $E_{t},l_{E,t},H_{E,t},K_{E,t},K_{H,t},z_{KE,t},N_{H,t},N_{S,t}$:

$$\frac{(1-\eta)}{C_{E,t} - \gamma_{t}C_{E,t-1}} = u_{CE,t},$$

(A.4a)

$$u_{CE,t} \left[ 1 - \lambda_{E,t} - \frac{\partial c_{KE,t}}{\partial K_{E,t}} \right] = \beta_{E}E_{t} \left[ u_{CE,t+1} \left( \frac{R_{E,t}}{\pi_{t+1}} - \lambda_{E,t}q_{t+1}^{1/\sigma_{t+1}} \right) \right],$$

(A.4b)

$$u_{CE,t} \left[ q_{t} - \lambda_{E,t}(1-\rho)A_{ME,t}H_{E,t}E_{t} \left( \frac{q_{t+1}^{1/\sigma_{t+1}}}{R_{E,t+1}} \right) \right] = \beta_{E}E_{t} \left[ u_{CE,t+1} \left( \frac{R_{E,t+1}}{\pi_{t+1}} - \lambda_{E,t}q_{t+1}^{1/\sigma_{t+1}} \right) \right],$$

(A.4c)

$$u_{CE,t} \left[ z_{KE,t} - \lambda_{E,t}m_{KE,t}(1-\rho)A_{ME,t} \right] = \beta_{E}E_{t} \left[ u_{CE,t+1} \left( \frac{R_{K,t+1}z_{KE,t+1}}{\pi_{t+1}} + 1 - \frac{\partial c_{KE,t+1}}{\partial K_{E,t+1}} \right) \right].$$

(A.4d)

$$R_{M,t}^{2}K_{H,t} = \frac{\sigma_{t}^{1/\sigma_{t}}}{X_{t}K_{H,t}},$$

(A.4e)

$$R_{K,t} = \frac{\partial c_{KE,t}}{\partial K_{E,t}},$$

(A.4f)

$$w_{H,t}(1+\rho_{E})A_{ME,t}m_{N_{t+1}}l_{E,t} = \left(1-a-c(1-\sigma_{t})W_{t}^{v} \right) \frac{1}{X_{t}N_{H,t}},$$

(A.4g)

$$w_{S,t}(1+\rho_{E})A_{ME,t}m_{N_{t+1}}l_{E,t} = \left(1-a-c(1-\sigma_{t})W_{t}^{v} \right) \frac{1}{X_{t}N_{S,t}},$$

(A.4h)

where I have re-written this latter set of conditions to have $R_{V,t}^{2} = \frac{\sigma_{t}^{1/\sigma_{t}}}{X_{t}H_{E,t}}$ in (A.4e) and $R_{K,t} = \frac{\sigma_{t}^{1/\sigma_{t}}}{X_{t}K_{E,t}}$ in (A.4d) and (A.4d) to simplify notation.

External adjustment cost functions:

$$ac_{KH,t} = \frac{\phi_{KH}}{2} \left( \frac{K_{H,t} - K_{H,t-1}}{K_{H}} \right)^{2},$$

(A.5a)

$$ac_{DH,t} = \frac{\phi_{DH}}{2} \left( \frac{d_{t} - d_{t-1}}{d} \right)^{2},$$

(A.5b)

$$ac_{SS,t} = \frac{\phi_{SS}}{2} \left( \frac{l_{S,t} - l_{S,t-1}}{l_{S}} \right)^{2},$$

(A.5c)

$$ac_{DB,t} = \frac{\phi_{DB}}{2} \left( \frac{d_{t} - d_{t-1}}{d} \right)^{2},$$

(A.5d)

$$ac_{EB,t} = \frac{\phi_{EB}}{2} \left( \frac{l_{E,t} - l_{E,t-1}}{l_{E}} \right)^{2},$$

(A.5e)

$$ac_{SB,t} = \frac{\phi_{SB}}{2} \left( \frac{l_{S,t} - l_{S,t-1}}{l_{S}} \right)^{2},$$

(A.5f)

$$ac_{EE,t} = \frac{\phi_{EE}}{2} \left( \frac{l_{E,t} - l_{E,t-1}}{l_{E}} \right)^{2},$$

(A.5g)
Consider retailer $j$'s maximization problem

$$\text{max}_{P_t^j} \quad \mathbb{E}_t \left\{ \sum_{i=0}^{\infty} \theta^i \mu_{t+i} \left[ \frac{P_t^j}{P_{t+i}} \cdot Y_{t+i}^*(j) - \frac{\delta_{P}^i}{P_{t+i}} Y_{t+i}^*(j) \right] \right\}$$

subject to the sequence of demand constraints

$$Y_{t+i}^*(j) = \frac{P_{t+i}^j}{P_{t+i}} Y_{t+i}$$

In words, the retailer must choose the optimal price to maximise profits without knowing when she will be able to re-optimize. Plugging $Y_{t+i}^*(j) = \frac{P_{t+i}^j}{P_{t+i}} Y_{t+i}$ into the objective function, taking the first-order condition with respect to $P_t^j$, denoting $\frac{\delta_{P}^i}{P_{t+i}} = mc_{t+i}$ the real marginal cost, and re-arranging gives

$$\mathbb{E}_t \left\{ \sum_{i=0}^{\infty} \theta^i \mu_{t+i} \left[ \frac{P_t^j}{P_{t+i}} \right]^c (1 - \epsilon) + mc_{t+i} \left[ \frac{1}{P_t^j} \right]^{1-c} \left[ P_{t+i}^j \right] Y_{t+i} \right\} = 0$$

Multiplying both terms inside the brackets by $\frac{P_{t+i}^j}{P_{t+i}}$ gives

$$\mathbb{E}_t \left\{ \sum_{i=0}^{\infty} \theta^i \mu_{t+i} \left[ P_{t+i}^j \right] P_{t+i}^{c-1} Y_{t+i} + \frac{\epsilon}{1-\epsilon} mc_{t+i} Y_{t+i} \right\} = 0$$

Solving for $P_t^j$ and making explicit the expression for the pricing kernel yields

$$P_t^j = \frac{\epsilon}{\epsilon - 1} \mathbb{E}_t \left\{ \sum_{i=0}^{\infty} \left[ \beta H \theta \right]^i \mu_{t+i} \left[ C_{H,t+i} \right] mc_{t+i} P_{t+i}^{c-1} Y_{t+i} \right\}$$

Now notice that there are no terms on the right-hand side of the equation that depend are idiosyncratic to retailer $j$. Therefore, it must be that all retailers set the same optimal reset price (Yan, 1996). Hence $P_t^j = P_t^*$. Now consider dynamic inflation indexation:

A retailer who can optimally reset the price will actually charge the nominal price just derived, but if she cannot reset the price, she will partially index it to lagged inflation at a degree $\chi \in [0, 1]$; Therefore, the price she charges if she cannot readjust will be

$$P_t(j) = (\pi_{t-1})^{\chi} P_{t-1}(j)$$

By iterating forward, it follows that if by $t+i$ a retailer who could adjust at time $t$ has not managed to reset her price again, the price she will charge at that time will be

$$P_{t+i}(j) = \left( \frac{P_{t+i-1}}{P_{t+i}} \right)^{\chi} P_t^*$$

where I have exploited the useful fact that $\prod_{k=0}^{i-1} \pi_{t+k} = \frac{P_{t+i}}{P_{t+i-1}} \times \ldots \times \frac{P_{t+i-3}}{P_{t+i-2}} = \frac{P_{t+i-1}}{P_{t+i-2}}$ after cross-cancelling.

Using (B.7) and the symmetric condition $P_t^*(j) = P_t^*$, it is therefore possible to rewrite (B.5) as

$$P_t^* = \frac{\epsilon}{\epsilon - 1} \mathbb{E}_t \left\{ \sum_{i=0}^{\infty} \left[ \beta H \theta \right]^i \mu_{t+i} \left[ C_{H,t+i} \right] \left( \frac{P_{t+i-1}}{P_{t+i}} \right)^{-\chi} mc_{t+i} Y_{t+i} \right\}$$

Or

$$P_t^* = \frac{\epsilon}{\epsilon - 1} \frac{H_{t+1}}{H_{t+2}}$$
where $H_{1,t}$ and $H_{2,t}$ are two auxiliary variables that allow to express in recursive form the infinite sums that describe real marginal costs and real marginal revenues, such that respectively

$$H_{1,t} = U_H^t (C_{H,t}) m c c_t P^*_t Y_t + \theta \beta H \left[ \frac{P_t}{P_{t-1}} \right] \kappa_{H_{1,t+1}}, \quad (B.10a)$$

$$H_{2,t} = U_H^t (C_{H,t}) P^c_t Y_t + \theta \beta H \left[ \frac{P_t}{P_{t-1}} \right] \kappa_{H_{2,t+1}}. \quad (B.10b)$$

Therefore, in real terms

$$P^*_t = \frac{\epsilon}{\epsilon - 1} h_{1,2} P_t, \quad (B.11)$$

where now

$$h_{1,2} = P_t^{-\epsilon} H_{1,t} = U_H^t (C_{H,t}) m c c_t Y_t + \theta \beta H \kappa_{Y_t} \kappa_{H_{1,t+1}}, \quad (B.12a)$$

$$h_{2,1} = P_t^{-\epsilon} H_{2,t} = U_H^t (C_{H,t}) Y_t + \theta \beta H \kappa_{H_{2,t+1}}. \quad (B.12b)$$

Dividing (B.11) by the lag of the price level yields a revisitition of (B.9) in terms of optimal reset inflation, as follows

$$\pi_t^\star = \frac{\epsilon}{\epsilon - 1} h_{1,2} \pi_t. \quad (B.13)$$

### C. Constraints Expressed in Nominal Terms

#### C.1. Patient Households

##### C.1.1. Period Budget Constraint

The period budget constraint of the patient households is given by

$$P_t C_{H,t} + P_t K^H_{H,t} + D_t + Q_t (H_{H,t} - H_{H,t-1}) + P_t a^K H_{H,t} + P_t a^C D_{H,t} \cdot \frac{R_{M,^2}}{A_{K,t}}$$

$$= \left( R_{M,^2} K_{H,t} + \frac{1 - \delta_{K} H_{t}}{A_{K,t}} \right) P_t K_{H,t-1} + R_{H,t-1} D_{t-1} + W_{H,t} N_{H,t} + F_{H,t}, \quad (C.1)$$

where $F_{H,t}$ is the nominal dividend rebated to the households by the retail firm, which they own.

After dividing both sides by $P_t$, focus on the gross return on previous period's deposits, $\frac{R_{H,t-1} D_{t-1}}{P_{t-1}}$.

Dividing both the numerator and the denominator by $P_{t-1}$ and defining $\frac{D_{t-1}}{P_{t-1}} = d_{t-1}$ yields

$$\frac{R_{H,t-1}}{P_{t-1}} d_{t-1}. \quad (C.2)$$

where $P_t = \frac{P_{t-1}}{P_{t-2}}$ is the gross rate of money inflation.

The budget constraint in real terms is therefore given by

$$C_{H,t} + K_{H,t} d_t + q_t (H_{H,t} - H_{H,t-1}) + a^K H_{H,t} + a^C D_{H,t} \cdot \frac{R_{M,^2}}{A_{K,t}}$$

$$= \left( R_{M,^2} K_{H,t} + \frac{1 - \delta_{K} H_{t}}{A_{K,t}} \right) K_{H,t-1} + \frac{R_{H,t-1}}{R_{H,t}} d_{t-1} + w_{H,t} N_{H,t} + F_{H,t}. \quad (C.3)$$

where $\Pi_{H,t}$ denotes the real dividend $\frac{F_{H,t}}{P_{t-1}}$.

#### C.2. Impatient Households

##### C.2.1. Budget Constraint

$$P_t C_{S,t} + q_t (H_{S,t} - H_{S,t-1}) + R_{S,t-1} L_{S,t-1} - P_t \gamma_{H,t} + P_t a^S S_{H,t} = L_{S,t} + W_{S,t} N_{S,t} \quad (C.4)$$

Using the same mathematics as in the previous section, the budget constraint in real terms is therefore given by

$$C_{S,t} + q_t (H_{S,t} - H_{S,t-1}) + \frac{R_{S,t-1}}{P_{t-1}} L_{S,t-1} - \gamma_{H,t} + a^S S_{H,t} = L_{S,t} + w_{S,t} N_{S,t} \quad (C.5)$$
C.2. Borrowing Constraint

The period borrowing constraint of the impatient households is given by

\[ l_{S,t} \leq P_t l_{S,t-1} + (1-\rho_S) m_{S,t} A_{MH,t} \varepsilon_t \left( \frac{Q_t + H_{S,t}}{R_{S,t}} \right) \]  

(C.6)

Dividing by \( P_t \), re-writing as in the previous section yields

\[ l_{S,t} \leq P_t l_{S,t-1} + (1-\rho_S) m_{S,t} A_{MH,t} \varepsilon_t \left( \frac{Q_t + H_{S,t}}{R_{S,t}} \right) \]  

(C.7)

which gives

\[ l_{S,t} \leq P_t l_{S,t-1} + (1-\rho_S) m_{S,t} A_{MH,t} \varepsilon_t \left( \frac{Q_t + H_{S,t}}{R_{S,t}} \right) \]  

(C.8)

Note that throughout this latter derivation I have introduced time variation in the LTV ratio.

C.3. Bankers

C.3.1. Budget Constraint

The bankers’ budget constraint is given by

\[ P_t C_{B,t} + R_{H,t-1} D_{t-1} + L_{E,t} + L_{S,t} + P_t \varepsilon_{EB,t} + P_t \varepsilon_{SB,t} = D_t + R_{E,t} L_{E,t-1} + R_{S,t} L_{S,t-1} - P_t \varepsilon_{H,t} \]  

(C.9)

After dividing both sides by \( P_t \) and making use of the trick \( \frac{P_t - 1}{P_t} \), the bankers budget constraint in real terms is

\[ C_{B,t} + \frac{R_{H,t-1} - \varepsilon_{H,t}}{\pi_t} = d_t + \frac{R_{E,t} - \varepsilon_{E,t}}{\pi_t} - \frac{R_{S,t}}{\pi_t} l_{S,t-1} - \varepsilon_{E,t} - \varepsilon_{H,t} \]  

(C.10)

C.3.2. Capital adequacy constraint

The capital adequacy constraint is given by

\[ L_t - D_t - \varepsilon_t [P_t \varepsilon_{t+1}] \geq \rho_D (L_t - D_t - \varepsilon_t [P_t \varepsilon_{t+1}]) + (1-\gamma_t) (1-\rho_D) (L_t - \varepsilon_t [P_t \varepsilon_{t+1}]) \]  

(C.11)

After dividing both sides by \( P_t \) and making use of the trick \( \frac{P_t - 1}{P_t} \), the bankers’ capital adequacy constraint in real terms is

\[ l_t - d_t - \varepsilon_t [P_t \varepsilon_{t+1}] \geq \rho_D \left( \frac{l_{t-1}}{\pi_t} - \frac{d_{t-1}}{\pi_t} - \varepsilon_t [P_t \varepsilon_{t+1}] \right) + (1-\gamma_t)(1-\rho_D)(l_{t-1} - \varepsilon_t [P_t \varepsilon_{t+1}]) \]  

(C.12)

which can be reinterpreted as a constraint on the ability of the bank to issue liabilities

\[ d_t \leq \rho_D \left( \frac{l_{t-1}}{\pi_t} - \frac{d_{t-1}}{\pi_t} - \varepsilon_t [P_t \varepsilon_{t+1}] \right) + (1-\gamma_t)(1-\rho_D)(l_{t-1} - \varepsilon_t [P_t \varepsilon_{t+1}]) \]  

where in the last step I have used the fact that \( l_t = l_{E,t} + I_{S,t} \) and \( e_t = e_{E,t} + e_{H,t} \).

Note that throughout this latter derivation I have introduced time variation in the capital-asset ratio.

C.4. Entrepreneurs

C.4.1. Budget Constraint

The budget constraint for the entrepreneurs is given by

\[ P_t C_{E,t} + \frac{K_{E,t}}{\pi_t} + Q_t (H_{E,t} - H_{E,t-1} - L_{E,t} + L_{S,t} - 1) + R_{E,t} L_{E,t-1} + W_{H,t} N_{H,t} + W_{S,t} N_{S,t} + R_{M,t} \varepsilon_{KH,t} + P_t \varepsilon_{KE,t} + P_t \varepsilon_{KE,t} = \pi_t Y_t + 1 - \delta_{KE,t} P_t K_{E,t} - 1 + L_{E,t} + P_t \varepsilon_{E,t} \]  

(C.14)

After dividing both sides by \( P_t \) and making use of the trick \( \frac{P_t - 1}{P_t} \), the entrepreneurs’ budget constraint constraint in real terms is

\[ C_{E,t} + \frac{K_{E,t}}{\pi_t} + Q_t (H_{E,t} - H_{E,t-1} - L_{E,t} + L_{S,t} - 1) + R_{E,t} L_{E,t-1} + W_{H,t} N_{H,t} + W_{S,t} N_{S,t} + R_{M,t} \varepsilon_{KH,t} + K_{E,t-1} + \varepsilon_{KE,t} + \varepsilon_{KE,t} = \frac{Y_t}{\pi_t} + 1 - \delta_{KE,t} K_{E,t} - 1 + L_{E,t} + \varepsilon_{E,t} \]  

(C.15)

where in the last step I have used the fact that \( \frac{P_t}{\pi_t} \) is the real marginal cost of production, or equivalently, the inverse of the gross mark-up of the final good price \( P_t \) over the intermediate output price \( P_t^{SE} \).
C. Marchesini / Optimal Monetary Policy, Macroprudential Instruments, and the Credit Cycle

C.4.2. Borrowing constraint

\[ L_{E,t} \leq \rho_E L_{E,t-1} + \left(1 - \rho_E\right) A_{ME,t} \left( m_{H,t} E_t \left( \frac{Q_{t+1}}{R_{E,t+1}} H_{E,t} \right) + m_{K,t} P_t K_{E,t} - m_N \left( W_{H,t} N_{H,t} + W_{S,t} N_{S,t} \right) \right) \]  
(C.16)

After dividing both sides by \( P_t \) and making use of the tricks for \( \frac{P_{t+1}}{P_t} \) and \( \frac{P_{t+1}}{P_t} \) as in the impatient households’ problem, the entrepreneurs’ borrowing constraint in real terms is

\[ l_{E,t} \leq \rho_E \frac{l_{E,t-1}}{\pi_t} + \left(1 - \rho_E\right) A_{ME,t} \left( m_{H,t} E_t \left( \frac{q_{t+1} \pi_{t+1}}{R_{E,t+1}} H_{E,t} \right) + m_{K,t} K_{E,t} - m_N \left( w_{H,t} N_{H,t} + w_{S,t} N_{S,t} \right) \right) \]  
(C.17)

Note that throughout this latter derivation I have introduced time variation in the LTVs on commercial real estate and capital for entrepreneurs.
D. Impulse Response Functions to a Positive Housing Demand Shock

Figure D.8: Impulse Response Functions to a Positive Housing Demand Shock

Notes: Time on the x-axis is measured in quarters of a year. The percentage deviation from the non-stochastic steady-state is measured on the y-axis. The time series in the graph originate from 2000 simulations.
Table 5: Optimal Monetary Policy: Welfare Maximization

<table>
<thead>
<tr>
<th>Technology Shock</th>
<th>Only LAW MP</th>
<th>MPP leads, LAW MP follows</th>
<th>Consumption Equivalent (CE) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\varrho_{\pi}$</td>
<td>4.00</td>
<td>4.00</td>
<td></td>
</tr>
<tr>
<td>$\varrho_{Y}$</td>
<td>0.15</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>$\varrho_{c}$</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>$\sigma_{\pi}^2$</td>
<td>0.027</td>
<td>0.021</td>
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</tr>
<tr>
<td>$\sigma_{Y}^2$</td>
<td>45.842</td>
<td>52.580</td>
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</tr>
<tr>
<td>$\sigma_{c}^2$</td>
<td>0.355</td>
<td>0.309</td>
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</tr>
<tr>
<td>$\sigma_{\pi}^2$</td>
<td>3.883</td>
<td>1.353</td>
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<tr>
<td>$W_{H,t}$</td>
<td>-215.0005</td>
<td>-214.9987</td>
<td>0.001</td>
</tr>
<tr>
<td>$W_{S,t}$</td>
<td>-42.2269</td>
<td>-42.2269</td>
<td>0.000</td>
</tr>
<tr>
<td>$W_{B,t}$</td>
<td>-50.8281</td>
<td>-50.8207</td>
<td>0.041</td>
</tr>
<tr>
<td>$W_{E,t}$</td>
<td>-31.2517</td>
<td>-31.2550</td>
<td>-0.020</td>
</tr>
<tr>
<td>$W_{society,t}$</td>
<td>-8.8168</td>
<td>-8.8165</td>
<td>0.030</td>
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</table>

Mortgage Default Shock: Entrepreneur

<table>
<thead>
<tr>
<th>Only LAW MP</th>
<th>MPP leads, LAW MP follows</th>
<th>Consumption Equivalent (CE) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\varrho_{\pi}$</td>
<td>1.60</td>
<td>1.50</td>
</tr>
<tr>
<td>$\varrho_{Y}$</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>$\varrho_{c}$</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>$\sigma_{\pi}^2$</td>
<td>0.010</td>
<td>0.005</td>
</tr>
<tr>
<td>$\sigma_{Y}^2$</td>
<td>0.226</td>
<td>0.198</td>
</tr>
<tr>
<td>$\sigma_{c}^2$</td>
<td>0.024</td>
<td>0.014</td>
</tr>
<tr>
<td>$\sigma_{\pi}^2$</td>
<td>0.101</td>
<td>0.032</td>
</tr>
<tr>
<td>$W_{H,t}$</td>
<td>-215.0180</td>
<td>-216.0185</td>
</tr>
<tr>
<td>$W_{S,t}$</td>
<td>-43.2302</td>
<td>-42.2303</td>
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<tr>
<td>$W_{B,t}$</td>
<td>-50.9005</td>
<td>-50.8992</td>
</tr>
<tr>
<td>$W_{E,t}$</td>
<td>-31.2496</td>
<td>-31.2497</td>
</tr>
<tr>
<td>$W_{society,t}$</td>
<td>-8.8210</td>
<td>-8.8209</td>
</tr>
</tbody>
</table>

Mortgage Default Shock: Impatient Household

<table>
<thead>
<tr>
<th>Only LAW MP</th>
<th>MPP leads, LAW MP follows</th>
<th>Consumption Equivalent (CE) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\varrho_{\pi}$</td>
<td>1.10</td>
<td>1.10</td>
</tr>
<tr>
<td>$\varrho_{Y}$</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>$\varrho_{c}$</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>$\sigma_{\pi}^2$</td>
<td>0.557</td>
<td>0.485</td>
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<tr>
<td>$\sigma_{Y}^2$</td>
<td>1.637</td>
<td>1.376</td>
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<tr>
<td>$\sigma_{c}^2$</td>
<td>0.262</td>
<td>0.232</td>
</tr>
<tr>
<td>$\sigma_{\pi}^2$</td>
<td>0.377</td>
<td>0.154</td>
</tr>
<tr>
<td>$W_{H,t}$</td>
<td>-214.9993</td>
<td>-214.9991</td>
</tr>
<tr>
<td>$W_{S,t}$</td>
<td>-42.2407</td>
<td>-42.2403</td>
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<tr>
<td>$W_{B,t}$</td>
<td>-51.1280</td>
<td>-51.1219</td>
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<tr>
<td>$W_{E,t}$</td>
<td>-31.2296</td>
<td>-31.2308</td>
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<tr>
<td>$W_{society,t}$</td>
<td>-8.8327</td>
<td>-8.8325</td>
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</table>

Notes: Grid search over $\varrho_{\pi} \in [1.1,4]$ with steps of 0.1, $\varrho_{Y} \in [0,1]$ with steps of 0.05, $\varrho_{c} \in [0,1]$ with steps of 0.01 for monetary policy, while for macroprudential policy $\varphi_{LLY} \in [-4,0]$ with steps of 0.2, $\varphi_{LYY} \in [-1,0]$ with steps of 0.05, $\varphi_{CCY} \in [-4,0]$ with steps of 0.2, $\varphi_{YCCY} \in [-1,0]$ with steps of 0.05. Variances are multiplied by $10^6$. The case with only monetary policy leaning against the wind is chosen as baseline to compute consumption equivalent.
Table 6: Optimal Monetary and Macroprudential Policy in a Multishock Scenario

<table>
<thead>
<tr>
<th></th>
<th>$\lambda_Y^{MP} = \lambda_Y^{MPP} = 0.012$</th>
<th>$\lambda_Y^{MP} = \lambda_Y^{MPP} = 0.0625$</th>
<th>$\lambda_Y^{MP} = \lambda_Y^{MPP} = 0.736$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Only LAW MPP leads, MP follows</td>
<td>Only LAW MPP leads, MP follows</td>
<td>Only LAW MPP leads, MP follows</td>
</tr>
<tr>
<td><strong>Monetary Policy</strong></td>
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<td></td>
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<tr>
<td>$\rho_\pi$</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
</tr>
<tr>
<td>$\rho_Y$</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>$\rho_c$</td>
<td>0.32</td>
<td>0.31</td>
<td>0.44</td>
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<tr>
<td><strong>Macroprudential Policy</strong></td>
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<td></td>
</tr>
<tr>
<td>$\varpi_{LTV}$</td>
<td>$-1.40$</td>
<td>$-1.60$</td>
<td>$-0.40$</td>
</tr>
<tr>
<td>$\varpi_Y^{LTV}$</td>
<td>$-0.05$</td>
<td>$-0.35$</td>
<td>$-1$</td>
</tr>
<tr>
<td>$\varpi_{CCyR}$</td>
<td>$-1.40$</td>
<td>$-2.00$</td>
<td>$-0.20$</td>
</tr>
<tr>
<td>$\varpi_Y^{CCyR}$</td>
<td>$-0.25$</td>
<td>$-0.90$</td>
<td>$-1$</td>
</tr>
<tr>
<td><strong>Selected Second Moments</strong></td>
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<tr>
<td>$\sigma_\pi^2$</td>
<td>3.977</td>
<td>4.182</td>
<td>4.444</td>
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<tr>
<td>$\sigma_Y^2$</td>
<td>263.622</td>
<td>259.747</td>
<td>258.927</td>
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<tr>
<td>$\sigma_c^2$</td>
<td>23.357</td>
<td>22.799</td>
<td>21.582</td>
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<tr>
<td>$\sigma_Y^2$</td>
<td>245.729</td>
<td>247.073</td>
<td>248.132</td>
</tr>
<tr>
<td>$\mathcal{L}_{MP,t}$</td>
<td>10.050</td>
<td>16.639</td>
<td>103.864</td>
</tr>
</tbody>
</table>

Notes: Grid search over $\rho_\pi \in [1.1, 4]$ with steps of 0.1, $\rho_Y \in [0.1]$ with steps of 0.05, $\rho_c \in [0.1]$ with steps of 0.01 for monetary policy, while for macroprudential policy $\rho_{LTV} \in [-4, 0]$ with steps of 0.2, $\rho_Y^{LTV} \in [-1, 0]$ with steps of 0.05, $\varpi_{CCyR} \in [-4, 0]$ with steps of 0.2, $\varpi_Y^{CCyR} \in [-1, 0]$ with steps of 0.05. Shocks are calibrated as in Iacoviello (2015). Variances are multiplied by $10^6$. Set of shocks: ‘animal spirits’ preference shock to the demand for consumption and housing jointly, the housing preference shock, the shocks to borrowing standards on business and household loans, i.e. LTV shocks, the investment-specific technology shock, as well as the two redistributive shocks and the standard technology shock.