GRAPE Group for Research in APplied Economics

GRAPE Working Paper # 37

Macroprudential and monetary policy rules in a model with collateral constraints

Piotr Żoch

FAME | GRAPE, 2019

Foundation of Admirers and Mavens of Economics
Group for Research in Applied Economics

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University of Chicago,
FAME | GRAPE

Abstract
We compare welfare and macroeconomic effects of monetary policy and macroprudential policy, in particular targeting loan-to-value (LTV) ratios. We develop a DSGE model with collateral constraints and two types of agents. In this setup, we study seven potential policy rules responding to credit growth and fluctuations in prices of collateral. We show that monetary policy responding to deviations of collateral prices from their steady state value results in the highest level of social welfare. It is also useful in stabilizing output and inflation. Macroprudential policy using LTV ratio as the instrument is dominated in terms of output and inflation stability by the interest rate rules. If interest rate rules are not available, the LTV ratio can be used to improve welfare, but gains are small..

Keywords:
collateral constraint, financial friction, macroprudential policy

JEL Classification
E30; E32; E44; E52

Corresponding author
Piotr Żoch, p.zoch@grape.org..pl

Acknowledgements
The earlier version of this paper was the author's undergraduate thesis supervised by Krzysztof Makarski and defended in 2013. The author would like to thank Krzysztof Makarski and Joanna Tyrowicz for extremely useful comments and suggestions. The remaining errors are ours.

Published by: FAME | GRAPE
ISSN: 2544-2473

Foundation of Admirers and Mavens of Economics
ull. Mazowiecka 11/14
00-052 Warszaw
Poland

W | grape.org.pl
E | grape@grape.org.pl
TT | GRAPE_ORG
FB | GRAPE.ORG
PH | +48 799 012 202

1 Introduction

The Global Financial Crisis has reignited research into the links between the financial system stability and monetary policy. In 2008, after incurring significant losses to their balance sheets, banks restricted lending, thus spilling the shock to the real economy. The severity and the length of this recession forcefully illustrate the paramount importance of financial system stability for the business cycle. Macroeconomic models increasingly incorporate interactions between financial and real economy, especially the frictions which are prevalent in financial intermediation. The emerging macroeconomic literature studying optimal policy addressing the business cycle has refined the treatment of the financial sector building on earlier models with financial frictions, notably Kiyotaki and Moore (1997) as well as Bernanke et al. (1999).[1]

In particular, the literature studies the advantages and disadvantages of conducting independent monetary policy and macroprudential policy. One potential approach is to enrich conventional monetary policy with macroprudential objectives.[2] Naturally, using the monetary policy instrument rate to mitigate the financial crises may require sacrificing traditional goals of central bankers: achieving price and output stability, as pointed out by Bernanke and Gertler (2000). Hence another potential approach which is to consider a setup with separate monetary and macroprudential policies: the central bank follows the Taylor rule, while another regulatory authority is responsible for regulating the financial sector. Considered policies focus particularly limiting excessive credit growth and stabilizing asset prices. One of the key instruments at the disposal of macroprudential policy is the loan-to-value (LTV) regulation. This instrument is widely used across many developed and developing countries. LTV is also utilized by Financial

[1] Brzoza-Brzezina et al. (2013a) provide an anatomy of DSGE models with financial frictions.

[2] For example, Curdia and Woodford (2010, 2016) modify the Taylor rule to include a response to credit spreads and variations in aggregate credit. Gray et al. (2011) propose that the Taylor rule should account for systemic risk in the financial sector.

Supervision in Poland. LTV is usually used in context of mortgages and housing market. In this paper we abstract from housing altogether and study the effects of changes in LTV ratio when it is applied to borrowing against productive capital.[3] The main objective of this article is to explore macroeconomic consequences of utilizing LTV as an instrument of independent macroprudential policy. This strand of the literature is particularly relevant from the policy perspective, as many countries operate independent macroprudential and monetary policy, especially in the aftermath of 2008 financial meltdown.

To this aim, our study provides a DSGE model in the spirit of Iacoviello (2005). There are two types of agents: impatient entrepreneurs and patient households. The former can borrow only via financial intermediaries and are constrained in taking loans by the value of their collateral. This modeling assumption is similar to Kiyotaki and Moore (1997), who also assume that impatient agents are more productive. Only physical capital, used also in production of goods, serves the purpose of collateralizing the debt. Instead of assuming that the collateral constraint is always binding, we allow it to be binding only occasionally. Banking sector in modeled as in Gerali et al. (2010). Nominal rigidities are introduced using Calvo (1983) scheme, similarly to Bernanke et al (1999). Financial intermediaries face adjustment costs and operate in the monopolistically competitive markets modeled using CES aggregator.

We use this model to examine seven different monetary-macroprudential regimes and compare how well they fare in stabilizing output and inflation. First, we analyze monetary policy that follows a standard Taylor rule without paying attention to any financial variables. Second, we study three augmented monetary policy rules – in addition to output and inflation they respond to collateral prices, credit growth and

[3] We can alternatively treat capital in our model as a bundle of productive capital such as machines or equipment and commercial real estate.

changes in collateral prices respectively. Finally, we study three combinations of standard Taylor rule with macroprudential rules. In these regimes, the LTV ratio is adjusted in response to the three aforementioned financial variables. To assess these monetary-macroprudential regimes we calculate welfare of the two types of agents present in our model. As the presence of heterogeneity makes conclusions based on social welfare sensitive to particular choices of Pareto weights attached to both types of agents, we also consider the ad-hoc loss function of central bank. According to this function, rules that result in lower variances of output and inflation are considered more desirable.

Our main findings are as follows. Social welfare is maximized under the interest rate rule that responds to deviations of collateral prices from their steady state. However, such a policy is beneficial for the borrowers and harmful for the patient agents. When we use the ad-hoc loss function of central bank this rule is the one that results in the biggest variances of output and inflation and thus it is unlikely that any monetary policy authority would adopt this regime. Among macroprudential rules using LTV ratio as the instrument, the one that reacts to capital prices deviations result in the lowest welfare loss which is, however, still higher than under two interest rate policies. We also conclude that interest rate rules allow for a better tradeoff between inflation and output stability than the LTV rules.

This paper in organized as follows. Section 2 is the literature review, Section 3 describes the model and Section 4 its calibration. Section 5 discusses the policy experiments and reports the results. We summarize this study by drawing policy recommendations and formulating potential avenues for further research.

2 Insights from previous literature

One way to reduce dangers originating from the financial sector is to implement monetary policy rules that take financial imbalances into account. There are however some caveats: using the policy rate to avoid crises generated by financial disturbances may require sacrificing traditional goals of central bankers - achieving price and output stability. Increasing the interest rate to prevent debt build-ups or asset bubbles may adversely affect the real economy. Objections of this type were raised by Bernanke and Gertler (2000). They argue that flexible inflation targeting is sufficient to maintain financial stability. Adjusting the policy rate in response to changes in asset prices may be actually destabilizing, especially under accommodative policy rule. Furthermore, it is sometimes impossible to conduct the independent monetary policy (as in the Eurozone) and different ways of stabilizing the financial sector may be sought as the remedy.

One possible solution is to use macroproducential policy – a set of tools such as capital requirements and loan-to-value ratios. The range of macroprudential instruments is very wide and encompasses loan provisioning rules, intensity of supervisory process, liquidity requirements or even discretionary warnings issued by the authority. Jeanne and Korinek (2018) show that taxation on borrowing that induces borrowers to internalize externalities resulting from credit booms and busts can be successfully used as a macroprudential tool. The potential advantage of conducting separate macroprudential policy is that it may not require sacrificing goals of stable prices and output or can even reinforce the monetary policy in pursuing these goals. However, in case of some types of shocks, maintaining financial stability may be conflicting with reducing the price volatility. Kannan, Rabanal and Scott (2012) argue that macroprudential policy reacting to the lagged growth of credit can be actually erroneous. In their model, when there is a total factor productivity shock leading to the growth of lending, restricting access to credit decreases welfare. They conclude that sticking to the macroprudential rule with the same values of parameters in case of every type of shock is misguided. It is important to observe the source of credit growth. Lambertini, Mendicino and Punzi (2017) introduce expectation-driven cycles to a model with housing sector and show that strict inflation targeting is suboptimal in this framework. Monetary rules responding to the rate of growth of housing prices or aggregate credit are welfare improving, but the maximal level of social welfare is attained under the policy reacting to credit growth. Counter-cyclical macroprudential policy taking the form of LTV ratio adjustments is more effective in stabilizing credit growth because it affects lending conditions directly without significant increases in the volatility of inflation typically accompanying efforts of reducing credit volatility using the interest rate. However, it is difficult to directly compare welfare under both regimes due to heterogeneity of agents - savers are better off under interest rate policy, lenders prefer the LTV policy. Carrasco-Gallego and Rubio (2012) evaluate performance of a rule on the loan-to-value ratio interacting with monetary policy and conclude that such combination is unambiguously increasing welfare although marginal benefits from performing separate macroprudential policy are negligible if central bank is already focused on the stabilization of output gap and collateral price. Angeloni and Faia (2013) investigate interactions between monetary policy and bank capital regulation when banks are exposed to runs. Pro-cyclical capital requirements such as BASEL II tend to amplify shocks, resulting in welfare losses caused by the increased volatility of macroeconomic variables. Optimal policy in their framework calls for aggressive responses with the policy rate to asset prices or bank leverage and mildly anticyclical capital ratios.

While the previous literature offered an insight into various tradeoffs concerning financial stability and fulfillment of traditional central bank mandate it rarely paid attention to heterogeneity. Our comprehensive study of multiple policy rules shows that interests of different agents are usually not aligned.

3 Model

3.1 Households

There is a continuum of measure one households indexed by ι. Every household maximizes a lifetime utility function given by:

$$E_0\left\{\sum_{t=0}^{\infty}\beta^t\left[\upsilon_t\frac{(C_t(\iota)-hC_{t-1})^{1-\theta}}{1-\theta}-\frac{N_t^{1+\varphi}(\iota)}{1+\varphi}\right]\right\}$$

which depends on current consumption $C_t(i)$, lagged group consumption C_{t-1} and supplied labor $N_t(\iota)$. The parameter h measures the degree of external habit formation in consumption, the parameter. θ is the inverse of the intertemporal elasticity of substitution, φ is the inverse of the Frisch elasticity of labor supply. β denotes the household's discount rate. Moreover, there is also a preference shock represented by υ_t which follows AR(1) process with standard deviation of innovation σ_υ and persistence ρ_υ . Household's decisions are subject to the following (real) budget constraint:

$$C_t(\iota)+D_t(\iota)+T_t(\iota)=(1-\tau_w)w_t(\iota)N_t(\iota)+\frac{R_{t-1}D_{t-1}(\iota)}{\Pi_t}+Div_t(\iota)$$

Household ι collects its after-tax labor income $(1-\tau_w)w_t(\iota)N_t(\iota)$ where $w_t(\iota)$ is the real wage, τ_w is the labor income tax, and real gross interest income on last period deposits is $\frac{R_{t-1}D_{t-1}(\iota)}{\Pi_t}$, where Π_t is the gross rate of inflation (defined as $\frac{P_t}{P_{t-1}}$) and R_{t-1} is the gross nominal interest rate. Observe that the interest rate is set in the previous period and remains unchanged regardless of inflation. The household's expenses consist of consumption, (real) deposits to be made this period $D_t(\iota)$ and lump-sum taxes $T_t(\iota)$. $Div_t(\iota)$ denotes dividends received from banks and firms (households own capital producers, retailers and both wholesale and retail branches of banks).

3.2 Labor market

Perfectly competitive labor aggregators combine differentiated labor services of households into a single homogeneous input denoted by N_t according to the following technology:

$$N_t = \left[\int_0^1 N_t(\iota)^{\frac{\phi_w - 1}{\phi_w}} d\iota\right]^{\frac{\phi_w}{\phi_w - 1}}$$

where ϕ_w is the elasticity of substitution between various type of labor. Profit maximization implies that household ι faces demand for its labor services given by

$$N_t(\iota) = \left(\frac{w_t(\iota)}{w_t}\right)^{-\phi_w} N_t$$

where w_t is the real wage index:

$$w_t = \left[\int_0^1 w_t(i)^{1-\phi_w} di\right]^{\frac{1}{1-\phi_w}}$$

In each period, a randomly and independently chosen fraction $1-\Psi_W$ of households is able to set their wages optimally. The remaining households can only index nominal wages to lagged and steady state inflation. This results in the following expression for the period *t* real wage of the household unable to reoptimize:

$$w_t(\iota) = w_{t-1}(\iota) \frac{\Pi_{t-1}^{\Xi_w} \overline{\Pi}^{1-\Xi_w}}{\Pi_t}$$

where Ξ_w captures the degree of indexation of wages to the lagged inflation rate, $\bar{\Pi}$ is the steady state gross inflation.

3.3 Capital producers

Households own perfectly competitive capital producers. They buy final goods from retailers and produce new capital which replaces depreciated capital and enlarges the existing capital stock.

Capital producers incur quadratic adjustment costs specified as $\frac{\chi_X}{2}\left(\frac{X_t}{X_{t-1}}-1\right)^2 X_t$, where X_t denotes investment goods and $\chi_X > 0$ is an adjustment cost parameter. Their optimization problem is to choose X_t in every period in order to maximize expected real profits:

$$E_0\left\{\sum_{t=0}^{\infty} \Lambda_t\left[Q_t\left(\zeta_t X_t-\frac{\chi_X}{2}\left(\frac{X_t}{X_{t-1}}-1\right)^2 X_t\right)-X_t\right]\right\}$$

where Q_t is the period *t* real price of the capital. Λ_t measures discounted marginal utility (in real terms) that representative household derives from profits in period *t*. ζ_t is the investment specific technology shock following AR(1) process with standard deviation of the innovation σ_ζ and autocorrelation ϱ_ζ. Aggregate capital stock in the economy evolves according to:

$$K_t=(1-\delta)K_{t-1}+\zeta_t X_t-\frac{\chi_X}{2}\left(\frac{X_t}{X_{t-1}}-1\right)^2 X_t$$

3.4 Entrepreneurs

Our model economy is populated by a continuum of measure one of entrepreneurs indexed by *j*.

They derive utility from their own consumption and maximize the following utility function:

$$E_0\left\{\sum_{t=0}^{\infty} \beta_e^t \frac{\left(C_t^e(j)-hC_{t-1}^e\right)^{1-\theta}}{1-\theta}\right\}$$

Where $C_t^e(j)$ is used to denote entrepreneur's j consumption, C_t^e represents aggregate entrepreneurial consumption, θ is the inverse of the intertemporal elasticity of substitution. Entrepreneurs discount future utility more heavily that households: β_e is strictly lower than β. In order to maximize the discounted stream of lifetime utility, entrepreneurs choose optimal levels of entrepreneurial consumption, capital and labor. Inputs of labor and capital are combined to produce intermediate good $Y_t(j)$ according to the following formula:

$$Y_t(j) = Z_t K_{t-1}^{\alpha}(j) N_t^{1-\alpha}(j)$$

where Z_t is an exogenous AR(1) process for total factor productivity with standard deviation of innovation σ_Z and persistence ϱ_Z.

Entrepreneur's j optimization is subject to two constraints. First of them is the budget constraint expressed in real terms:

$$C_t^e(j) + Q_t K_t(j) + w_t N_t(j) + \frac{\int_0^1 R_{t-1}^B(g) B_{t-1}(j,g)dg}{\Pi_t}$$
$$= \frac{P_t^w}{P_t} Y_t(j) + B_t(j) + Q_t(1-\delta)K_{t-1}(j)$$

Expenditures on consumption, new capital, repayment of loans and hiring labor are financed by taking new loans, selling undepreciated capital at the end of each period and selling intermediate product in a competitive market to retailers (described in section 3.5) at the wholesale price P_t^w We use $B_t(j,g)$ to denote loans taken by the entrepreneur j from retail bank g ∈ [0,1]. These loans are aggregated as follows:

$$B_t(j) = \left[\int_0^1 B_t(j,g)^{\frac{\phi_B - 1}{\phi_B}} dg\right]^{\frac{\phi_B}{\phi_B - 1}}$$

where ϕ_B is the elasticity of substitution between loans extended by various banks g. The interest rate R_t^B is defined in the following way:

$$R_t^B = \left[\int_0^1 R_t^B(g)^{\frac{1}{1-\phi_B}} dg \right]^{1-\phi_B}$$

There is also the constraint on the maximum amount of borrowing. The amount of resources that banks are willing to lend is limited by the value of the undepreciated capital held by entrepreneurs. We follow Gerali et al. (2010) and depart from the assumption made in Iacoviello (2005), where entrepreneurs borrow only against commercial real estate. Stock of capital in our model can be interpreted as a bundle of productive capital (machines, equipment) and commercial real estate.

Specifically:

$$R_t^B B_t(j) \leq m_t E_t\{(1-\delta) Q_{t+1} K_t(j) \Pi_{t+1}\}$$

where m_t is the LTV ratio set by the macroprudential authority. The constraint does not have to be always binding.

3.5 Retailers and final goods producers

There is a continuum of measure one of monopolistically competitive retailers. Retail firms indexed by *i* purchase intermediate goods produced by firms owned by entrepreneurs in a competitive market and differentiate them costlessly. Perfectly competitive final goods producer then buys differentiated retail goods and converts them into final good according to:

$$Y_t = \left[\int_0^1 Y_t(i)^{\frac{\phi_p - 1}{\phi_p}} di \right]^{\frac{\phi_p}{\phi_p - 1}}$$

where ϕ_p is the elasticity of substitution between various type of intermediate retail goods. Profit maximization yields the following demand function for retail good *i*:

$$Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\phi_p} Y_t$$

where P_t is the price index:

$$P_t = \left[\int_0^1 P_t(i)^{1-\phi_p}\, di\right]^{\frac{1}{1-\phi_p}}$$

We assume that in each period only fraction $1-\Psi_P$ of retailers can freely adjust their prices. Those who are unable to do so can only update their previous period prices by lagged inflation and steady state inflation. That means that the price of retailer ι, who did not receive signal enabling her to set an optimal price, is equal to:

$$P_t(i) = P_{t-1}(i)\Pi_{t-1}^{\Xi_P}\overline{\Pi}^{1-\Xi_P}$$

where Ξ_P controls the degree of price indexation.

3.6 Banks

Banks are the only intermediaries between households and entrepreneurs. Beginning of period t real capital K_t^B accumulates according to the following law of motion:

$$\Pi_t K_t^B = (1-\delta^B)K_{t-1}^B + (1-div)J_{t-1}$$

δ^B measures resources needed for the management of bank, 1-div is the fraction of retained earnings and J_t is used to denote nominal profits or losses on banking activity.

Banks consist of two branches: retail and wholesale. Wholesale banks are perfectly competitive. They issue deposits D_t to households and pay interest R_t^D on them. Deposits are combined with bank capital and used to finance loans B_t^W to retail banks at the wholesale gross interest rate R_t^{BW}:

$$D_t + K_t^B = B_t^W$$

Wholesale banks are subject to quadratic penalty for deviating from the target leverage ratio ω^{reg} set by the macroprudential authority:

$$\frac{\omega^{\text{penalty}}}{2}\left(\frac{K_t^B}{B_t^W} - \omega^{reg}\right)^2 K_t^B$$

This penalty is paid to the government. The problem of the wholesale bank can be expressed as the maximization of

$$(R_t^{BW} - 1)B_t^W - (R_t^D - 1)\mathrm{D_t} - \frac{\omega^{\text{penalty}}}{2}\left(\frac{K_t^B}{B_t^W} - \omega^{reg}\right)^2 K_t^B$$

Solution to the above problem results in the expression for the spread between the policy rate and the wholesale lending rate:

$$Spread^{BW} = -\omega^{penalty}\left(\frac{K_t^B}{B_t} - \omega^{reg}\right)\left(\frac{K_t^B}{B_t}\right)^2$$

It shows that spreads are positive when the leverage ratio (i.e. ratio of loans to bank capital $\frac{K_t^B}{B_t}$) is higher than required.

There is a continuum of measure one of retail banks indexed by g. Each retail bank obtains funds $B_t^W(g)$ from wholesale banks, costlessly differentiates them, observes aggregate disturbance to the amount of funds available (to be discussed shortly) and then extends loans to entrepreneurs $B_t(g)$ by choosing the interest rate $R_t^B(g)$ to maximize its profits given by:

$$[R_t^B(g) - \frac{1}{\mu_t}R_t^{BW}]B_t(g)$$

subject to the following demand schedule derived from the cost minimization problem faced by every entrepreneur taking a loan:

$$B_t(g) = \left(\frac{R_t^B(g)}{R_t^B}\right)^{-\phi_B} B_t$$

where $B_t(g)$ is the amount of loans extended by the bank g and B_t is the overall volume of loans taken by entrepreneurs. We assume that the rate μ_t at which retail banks can channel resources from wholesale banks to entrepreneurs is time-varying. It follows an

AR(1) process with mean one, autocorrelation ρ_μ and standard deviation of innovation σ_{μ}..

Retail banks will set interest rates

$$R_t^B(g) = \frac{1}{\mu_t}\frac{\phi_B}{\phi_B - 1}R_t^{BW}.$$

Observe that the right-hand side of (26) is common across all retail banks implying that in the equilibrium:

$$R_t^B(g) = R_t^B.$$

Using this observation we note that $B_t(g) = B_t$ for all $g \in [0,1]$.

The total spread between the rate at which entrepreneurs can borrow and the policy rate increases when wholesale banks deviate from the target capital to loans ratio and when the financial shock μ_t decreases efficiency of retail banks. Total real profits of the entire banking group consisting of wholesale and retail banks are as follows:

$$J_t = \underbrace{R_t^B B_t - R_t^{BW} B_t^W}_{retail\ profits} + \underbrace{R_t^{BW} B_t^W - R_t^D D_t - K_t^B}_{wholesale\ profits} - \underbrace{\frac{\omega^{\text{penalty}}}{2}(\frac{K_t^B}{B_t^W} - \omega^{reg})^2 K_t^B}_{penalty}$$

3.7 Government, macroprudential and monetary policy

In the baseline version of the model, macroprudential authority sets constant capital adequacy ratio ω^{reg} and penalty for deviations from the target equal to $\omega^{penalty}$. LTV ratio is exogenous:

$$\frac{m_t}{\overline{m}} = \left(\frac{m_{t-1}}{\overline{m}}\right)^{\gamma_M} e^{\varepsilon_t^m}$$

where $\overline{m}$ is the steady state LTV ratio, ε_t^m represents i.i.d LTV ratio shock with standard deviation σ_m. γ_M captures the persistence of LTV ratio.

The central bank sets its policy rate R_t according to the following Taylor rule:

$$\frac{R_t}{\overline{R}} = \left(\frac{R_{t-1}}{\overline{R}}\right)^{\gamma_R} \left[\left(\frac{\Pi_t}{\overline{\Pi}}\right)^{\gamma_\Pi} \left(\frac{Y_t}{\overline{Y}}\right)^{\gamma_Y}\right]^{1-\gamma_R} e^{\varepsilon_t^R}$$

where γ_R controls the degree of instrument smoothing, γ_Π and γ_Y the strength of policy rate response to inflation and output. ε_t^R is an i.i.d interest rate shock with standard deviation σ_R.

Later on, in our numerical experiments, we change both macroprudential and monetary policies allowing for responses to developments on financial markets.

The government is assumed to buy a constant fraction $\overline{g}$ of the final output. Its expenditures are financed by revenues from labor income tax τ_w, sales tax τ_p and lump-sum taxes T_t in order to balance the budget in every period. In addition the government receives payments from wholesale banks, whenever they deviate from the target the target leverage ratio ω^{reg}.

3.8 Closing the model

To close the model we define the following set of aggregate variables:

$$K_t = \int_0^1 K_t(j)dj \quad C_t = \int_0^1 C_t(\iota)d\iota$$
$$C_t^e = \int_0^1 C_t^e(j)dj \quad D_t = \int_0^1 D_t(\iota)d\iota$$

All markets clear:

$$B_t = B_t^W \qquad N_t = \int_0^1 N(j)dj$$
$$\int_0^1 Y(i)di = \int_0^1 Y(j)dj$$

There is also the resource constraint:

$$Y_t = C_t + C_t^e + X_t + G_t$$

4 Calibration

We set steady state inflation $\overline{\Pi}$ equal to 1.0025 (half of the ECB target, to account for the fact that inflation was considerably below the target after the Great Recession) and discount factor of patient agents β to 0.995. β_e is set to 0.97, slightly lower than Iacoviello (2005) and similar to Iacoviello and Neri (2010) implying that credit constraint is binding in the steady state. Values of θ and φ, inverses of the elasticity of intertemporal substitution and Frisch elasticity of labor supply are set to 2, standard value in the literature. Habit formation parameter h is equal to 0.8 in our model. Depreciation rate δ is 0.025 while the elasticity of product with respect to capital α is 0.35.

Elasticities of substitution between various types of intermediate goods ϕ_p and labor ϕ_w are equal to 6. That means that steady state markups in the labor and product markets amount to 20%. Parameters Ψ_P and Ψ_W, the Calvo probabilities for prices and wages, are set to 0.6 and 0.9 respectively. That implies that the average duration of the wage contract is equal to 10 quarters and that the retailers are on average able to reset their prices twice per year. Our calibration of parameters governing price and wage dynamics is very similar to the estimates obtained by Smets and Wouters (2003). Indexation parameters Ξ_p and Ξ_w are equal to 0.5. The investment adjustment cost parameter χ_X is set to 12 to improve the fit of the model.

Target capital to loans ratio ω^{reg} is 0.1, above the requirements imposed by the Basel Accords, while the fraction of earnings paid out as dividends is equal to 0.15, the value that is lower than the average payout ratio presented in Onali (2012), but, as argued by Brzoza-Brzezina, Kolasa and Makarski (2013), very likely accurately reflecting more conservative dividend policy pervasive in recession-ridden Europe. The parameter $\omega^{penalty}$ measuring the penalties faced by banks deviating from target leverage ratio is set to 10, as proposed in Gerali et al. (2010). We calibrate ϕ_B at 203 to obtain the steady state spread between policy rate and retail lending rates equal to 200 bp annually. δ^B is 0.04625 to guarantee that banks satisfy the required leverage ratio in the steady state.

Parameters describing the behavior of the central bank are standard: response to inflation, $\gamma_{\Pi,}$ is 1.5 and response to deviations of output from its steady state level, $\gamma_{Y,}$ is 0.15. Smoothing parameter γ_R is set to 0.85. Steady state LTV ratio is set to 0.35. Estimates of this parameter vary a lot - from 0.2 if only short-term loans are considered to 0.9 when only real estate can be collateralized. Since loans in our model correspond more closely to the former, we pick a number on the lower end. It is similarly difficult to disciplineρ_m. This parameter is calibrated together with parameters governing stochastic processes. Finally, the fraction of output bought by the government $\overline{g}$ is set to 0.21. We introduce government expenditures in order to reduce household consumption in the steady state so that the share of household consumption in output matches the data. τ_w and τ_p are both negative and serve the purpose of eradicating any distortions originating from monopolistic competition in labor and goods markets in the steady state.

We calibrate parameters governing stochastic processes (persistence and standard deviation of innovations) as well as the LTV ratio smoothing parameter by using the Simulated Method of Moments. For any given choice of parameter values we calculate model-implied standard deviation, autocorrelation and correlation with output of consumption, investment, loans, inflation and spread between central bank rate and lending rate. We compute also standard deviation and autocorrelation of output. Model-implied moments are calculated using DynareOBC toolkit (see Holden (2016a) and Holden (2016b) for the description of the numerical procedure). We perform second order approximation of equilibrium conditions around the risky steady state. Our numerical procedure respects non-negativity of multipliers on the collateral constraint.[4] We simulate the model 2000 times for 300 periods. In each run we discard first 200 observations. We use the remaining 100 observations to calculate moments of interest. We search for parameter values that minimize squared deviations between model-implied moments and their empirical counterparts. To calculate the latter we use the Eurozone data for years 1999-2019.

Calibrated parameters are summarized in Table 1, calibration of stochastic processes is displayed in Table 2 while the most important steady state ratios are presented in the Table 3. Table 4 shows stochastic properties of the baseline model. Our model generates the standard deviations of output, consumption and investment not much different from the ones observed in the Eurozone in the period 1999-2019. Most importantly, it captures the fact that investment is much more volatile than consumption and output and that consumption is less volatile than output. It is less successful in matching the volatility of loans and inflation. The autocorrelation of variables is in line with the data, except investment, which is more persistent in our model than in the data. Our model can quite successfully replicate cyclical patterns seen in the Euro Area. Loans are very weakly procyclical (while they are acyclical in the data) and spreads are countercyclical. We are unable to match procyclicality of inflation. Overall, while the fit of the model is far from perfect we deem it to be satisfactory given the absence of many modeling ingredients commonly used in large-scale DSGE models. Moreover, the second half of our sample is characterized by persistently low interest rates, output and inflation. This accounts for the observed procyclicality of inflation. In this paper we completely abstract form the existence of the Effective Lower Bound on interest rates. Its presence would amplify demand shocks and lead to stronger correlation of output and inflation. In addition, we

[4] We check whether it holds in the calibrated model. We simulate the model 2000 times for 300 periods. The mean Lagrange multiplier on the collateral constraint is 0.66, the minimum is -3.4861e-13 and the multiplier is negative in 4.3% of periods. Given how close it is to 0 we judge our numerical procedure to be accurate.

completely abstract from shocks to price and wage Phillips curves. These kinds of shock are the most important drivers of business cycles through the lens of estimated DSGE models, such as Smets and Wouters (2003), and are key to improving the fit.

Table 5 presents the variance decomposition results. In our model productivity shocks do not play an important role in driving movement of most of the variables. Through the lens of our model they explain most of the variance of inflation. As these shocks push output and inflation in the opposite directions, we conjecture that this is the reason why we cannot match the procyclical character of inflation. Preference shocks, interest rate shocks and financial shocks have large contribution. Together they explain a significant fraction of variance of most macroeconomic variables. Preference shocks drive mostly consumption, while financial shocks affect mostly investment. These two types of shocks affect agents asymmetrically. A positive preference shock increases marginal utility of consumption of the savers. This leads to an increase in labor supply which increases output and thus also income of the borrowers (who gain capital share). An increase in inflation caused by relatively high aggregate demand will reduce real value of debt and allow entrepreneurs to increase consumption and investments. This effect is dampened by the response of the central bank, which raises its interest rate. As a consequence, investment does not move that much. A positive financial shock reduces interest rate at which entrepreneurs borrow. This relaxes their borrowing constraint and allows them to borrow more. They decide to use extra borrowing to purchase more capital as it allows them to enjoy higher consumption even when interest rate goes back to its original level. Resources to finance expansion need to come from increased savings of the patient agents. They reduce their consumption and supply more labor. Interest rate shocks have roughly equal impact on all considered variables. Shocks to LTV ratio and investment specific productivity shocks are of lesser importance.

5 Policy experiments

5.1 Description of analyzed policy regimes

In our numerical experiments we consider the baseline model in which the central bank is not directly concerned with developments in the financial sector and six further policy regimes that could be divided into two types.

The first type consists of simple monetary policy rules a'la Taylor (1999), but responding to 1) nominal credit growth rate, 2) deviations of (real) capital price Q from its steady state level, 3) capital price growth rate. In case of the first rule, the monetary authority raises the policy rate above the average level whenever aggregate credit increases and reacts by lowering the rate when the decline in the volume of loans extended to entrepreneurs is observed. This policy is designed in that way to dampen credit booms and inhibit credit busts. However, it is evident that if such an action fails to prevent sudden changes in the volume of credit it may prolong the period when credit deviates from its steady state level. The monetary policy carried out in line with the second rule increases the interest rate when the real capital price is above unity. As capital is the only collateral in our model, shocks that raise its price relax the credit constraint and encourage entrepreneurs to borrow more. Tightening stance of the monetary policy under these circumstances suppresses aforementioned debt build-up. On the other hand, such a blunt response may adversely affect the real economy by not allowing for necessary adjustments. The last policy rule belonging to this group aims for stabilizing capital prices by reacting to the rate of their change.

Formally, these policies are carried out according to the following formulas:

$$\frac{R_t}{\overline{\overline{R}}} = \left(\frac{R_{t-1}}{\overline{\overline{R}}}\right)^{\gamma_R} \left[\left(\frac{\Pi_t}{\overline{\overline{\Pi}}}\right)^{\gamma_\Pi} \left(\frac{Y_t}{\overline{\overline{Y}}}\right)^{\gamma_Y} \left(\frac{B_t}{B_{t-1}}\right)^{\gamma_{\Delta B}}\right]^{1-\gamma_R} e^{\varepsilon_t^R}$$

$$\frac{R_t}{\overline{R}} = \left(\frac{R_{t-1}}{\overline{R}}\right)^{\gamma_R} \left[\left(\frac{\Pi_t}{\overline{\Pi}}\right)^{\gamma_\Pi} \left(\frac{Y_t}{\overline{Y}}\right)^{\gamma_Y} \left(\frac{Q_t}{\overline{Q}}\right)^{\gamma_Q}\right]^{1-\gamma_R} e^{\varepsilon_t^R}$$

$$\frac{R_t}{\overline{R}} = \left(\frac{R_{t-1}}{\overline{R}}\right)^{\gamma_R} \left[\left(\frac{\Pi_t}{\overline{\Pi}}\right)^{\gamma_\Pi} \left(\frac{Y_t}{\overline{Y}}\right)^{\gamma_Y} \left(\frac{Q_t}{Q_{t-1}}\right)^{\gamma_{\Delta Q}}\right]^{1-\gamma_R} e^{\varepsilon_t^R}$$

where $\gamma_{\Delta B}$, $\gamma_Q$and $\gamma_{\Delta Q}$, measure the strength of response of the policy rate. Denote these rules by $TAYLOR^{\Delta B}$, $TAYLOR^{Q}$, and $TAYLOR^{\Delta Q}$ respectively.

The second type of policy regimes is characterized by the existence of the separate macroprudential authority. The central bank behaves in accord with the standard monetary rule (i.e. it does not use interest rate to directly respond to the set of variables discussed above). The macroprudential regulator sets the LTV ratio m_t to adjust the collateral constraint thus trying to counteract unfavorable developments in the financial market. Any shocks that result in the relaxed constraint (by e.g. increasing the capital price or shrinking spreads between policy and retail rates) are perceived by the macroprudential authority as the potential source of dangerous financial imbalances prompting it to decrease m_t. We consider three regimes of this type - each one of them responds to a different indicator variable: capital price, credit growth rate and capital price growth rate.

LTV requirements are not the only type of macroprudential policy that could be studied in our model. For example, Kiley and Sim (2017) prefer to focus on proportional tax on leverage. This would correspond to ω^{penalty} in our framework. They argue that any study of LTV ratio is subject to computational challenges due the fact that the collateral constraint is not necessarily always binding. They point out that the literature has typically ignored this challenge and assumed such constraints always bind. This is not the case in this paper. As emphasized earlier, our approach does not assume that the collateral constraint is constantly binding. If it is not binding, then small changes in LTV ratio do not affect borrowing decisions of entrepreneurs. Brzoza-Brzezina et al. (2013)

study capital adequacy ratio in a similar environment. Such a policy would work through changes in ω^{reg}.

Formulas describing LTV policies are as follows:

$$\frac{m_t}{\overline{\overline{m}}} = \left(\frac{m_{t-1}}{\overline{\overline{m}}}\right)^{\gamma_M} \left(\frac{B_t}{B_{t-1}}\right)^{-\gamma_{M\Delta B}(1-\gamma_M)} e^{\varepsilon_t^m}$$

$$\frac{m_t}{\overline{\overline{m}}} = \left(\frac{m_{t-1}}{\overline{\overline{m}}}\right)^{\gamma_M} \left(\frac{Q_t}{\overline{\overline{Q}}}\right)^{-\gamma_{MQ}(1-\gamma_M)} e^{\varepsilon_t^m}$$

$$\frac{m_t}{\overline{\overline{m}}} = \left(\frac{m_{t-1}}{\overline{\overline{m}}}\right)^{\gamma_M} \left(\frac{Q_t}{Q_{t-1}}\right)^{-\gamma_{M\Delta Q}(1-\gamma_M)} e^{\varepsilon_t^m}.$$

$\gamma_{M\Delta B}$, γ_{MQ}, $\gamma_{M\Delta Q}$ are all positive and describe the strength of the response. Denote rules these rules by $LTV^{\Delta B}$, LTV^{Q}, and $LTV^{\Delta Q}$ respectively.

We fix $\gamma_R, \gamma_\Pi, \gamma_Y, \gamma_M$ at the previously calibrated levels. We interpret our policy experiments as a hypothetical scenario in which the policymaker decided not to change her response to output fluctuations and inflation as well as the degree to which there is instrument smoothing. This leaves us with six new parameters that have to be chosen in a way that would allow us to make a meaningful comparison. We set these parameters to values that maximize social welfare (described below) subject to the requirement that the volatility of instruments (interest rate and LTV ratio) cannot be more than twice as big as in our baseline scenario. We can then interpret our comparison as between best (constrained) simple policy rules.[5]

5.2 Welfare analysis

Benigno and Woodford (2012) discuss the two approaches that have recently been used for welfare analysis in DSGE models. These approaches are either characterizing the

[5] Notice that if the macroprudential authority uses the LTV ratio as its instrument, it will cause movements in output and inflation which might force the central bank to adjust its policy rate. When we search for the optimal LTV rule parameters we assume that the macroprudential authority internalizes it and cannot choose policy response which would cause too large interest rate volatility.

optimal Ramsey policy, or solving the model using a second-order approximation to the structural equations for given policy and then evaluating welfare using this solution. We do not follow the literature on optimal policy under discretion or commitment, example of which is shown in Gali (2015). The size of the model as well as the presence of the occasionally binding constraint would make analytical derivation of optimal policy cumbersome – in contrast to a simple three equation New Keynesian model it would be of a limited value. Similarly to Schmitt-Grohe and Uribe (2004) our approach is purely numerical.

We define social welfare function as

$$WELFARE^{SOCIAL}(\lambda) = \lambda \int_0^1 E_0 \left\{ \sum_{t=0}^{\infty} \beta_e^t \frac{(C_t^e(j) - hC_{t-1}^e)^{1-\theta}}{1-\theta} \right\} dj + (1-\lambda) \int_0^1 E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[\upsilon_t \frac{(C_t(\iota) - hC_{t-1})^{1-\theta}}{1-\theta} - \frac{N_t^{1+\varphi}(\iota)}{1+\varphi} \right] \right\} d\iota$$

where λ is the Pareto weight on entrepreneurs (impatient agents). This is a standard utilitarian welfare function parametrized by λ. We follow Carrasco-Gallego and Rubio (2012) and choose Pareto weight λ^* in such a way that when evaluated in the deterministic steady state, the social welfare is just a simple sum of one-period utility functions (up to a scaling factor). Formally

$$\lambda^* = \frac{1-\beta_e}{2-\beta_e - \beta}.$$

Welfare under each regime is measured in seven different cases - in the model where all stochastic processes are active and parameterized as in Section 2 and in hypothetical economies where only one process is active (and parametrized as before). We will consider only the most important shocks (as shown in Table 5): productivity, preference and financial. This gives 28 scenarios in total (7 regimes multiplied by 4 cases).

Before presenting the results of our welfare analysis, we report optimal simple policy rules. For monetary policy rules we have $\gamma_{\Delta B} = 4.2$, $\gamma_{Q} = 0.6$, $\gamma_{\Delta Q} = 0.45$. For macroprudential rules we have $\gamma_{M\Delta B} = 11.7$, $\gamma_{MQ} = 1.2$ and $\gamma_{M\Delta Q} = 0.8$. In all of these cases policy rules result in the highest admissible instrument volatility.

We present the results of our analysis using consumption equivalents. Consumption equivalents measure the fraction of consumption in the steady state that should be taken from an agent in order to equalize her total steady state welfare with welfare under the evaluated policy in a dynamic model. Whenever this number is positive, it indicates that agents are better off in the steady state and switching from that situation to the one when stochastic processes are active is undesirable. More precisely, we search for consumption equivalents (denoted by Ω for patient and Ω^e for impatient agents) that satisfy the following set of equations:

$$\int_0^1 E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[\upsilon_t \frac{(C_t(\iota) - hC_{t-1})^{1-\theta}}{1-\theta} - \frac{N_t^{1+\varphi}(\iota)}{1+\varphi} \right] \right\} d\iota = \frac{1}{1-\beta} \left[\frac{((1-h)(1-\Omega)\overline{C})^{1-\theta}}{1-\theta} - \frac{N^{1+\varphi}}{1+\varphi} \right]$$

$$\int_0^1 E_0 \left\{ \sum_{t=0}^{\infty} \beta_e^t \frac{(C_t^e(j) - hC_{t-1}^e)^{1-\theta}}{1-\theta} \right\} dj = \frac{1}{1-\beta_e} \left[\frac{((1-h)(1-\Omega^e)\overline{C^e})^{1-\theta}}{1-\theta} \right]$$

In Table 6 we present the results of our analysis using consumption equivalents. To facilitate interpretation we multiply them by 100. Therefore consumption equivalent equal to 1 indicates that moving to a particular regime from the steady state is as bad a reduction in steady state consumption by 1%. We see that consumption equivalents are always positive, suggesting macroeconomic fluctuations are costly and both types of agents would prefer to get rid of them. The patient and the impatient in our model rank regimes differently. Borrowers prefer every policy rule to the baseline Taylor rule that responds to inflation and output deviations only. They benefit greatly from $TAYLOR^{Q}$. Moving to this regime from the current one would reduce consumption equivalent by 1.6pp (decline of business cycle cost by 80%). LTV^{Q} is the second-best rule for the borrowers. Gains are, however, much smaller: 0.7pp. Alternatively, $TAYLOR^{\Delta B}$ gives almost as big gains as the LTV policy responding to capital prices.

On the other hand, the savers would not prefer some policy rules to the baseline. For example moving to $TAYLOR^{\Delta Q}$ would increase consumption equivalent by 1pp. There are only two regimes they prefer to the baseline: $TAYLOR^{\Delta B}$ and $TAYLOR^{Q}$. Gains from debt stabilization are particularly large and would eliminate 90% of the cost of macroeconomic volatility. Capital price stabilization has smaller benefits, as it reduces consumption benefit by 0.4pp. Note that all LTV policies make the savers worse off.

To conclude which monetary/macroprudential regime would be chosen by the planner we define social (or representative agent) consumption equivalent as a number Ω^{SOCIAL} which solves:

$$\frac{1-\lambda}{1-\beta}\left[\frac{[(1-h)(1-\Omega^{SOCIAL})\overline{C}]^{1-\theta}}{1-\theta}-\frac{N^{1+\varphi}}{1+\varphi}\right]+\frac{\lambda}{1-\beta_e}\frac{[(1-h)(1-\Omega^{SOCIAL})\overline{C^e}]^{1-\theta}}{1-\theta}$$
$$=WELFARE^{SOCIAL}(\lambda).$$

Observe that for $\lambda=1$ it equals Ω^e while for $\lambda=0$ it is Ω. Since we used $\lambda=\lambda^*$ to find the optimal rules, we will compare consumption equivalents corresponding to $WELFARE^{SOCIAL}(\lambda^*)$.

Weights used in social welfare function favor the impatient agents. In fact, given our calibration, $\lambda^*=0.8571$. In our model the ranking of the representative agent very closely tracks the one of the borrowers. We conclude that $TAYLOR^{Q}$, the policy preferred by the borrowers and second-best for the savers, is the one that the planner should pursue. It would reduce cost of business cycle fluctuations by more than 60%. LTV policies are better than the baseline, but gains resulting from following them are small, associated with, at most, decrease in consumption equivalent by 0.4pp in case in which capital price are stabilized at their steady state level.

It is instructive to check whether the ranking varies if we consider the model in which only the single shock is active.[6] Table 7 shows the ranking for the productivity shock, Table 8 for the preference shock and Table 9 for the financial shock. Productivity shock noticeably changes the ranking. It renders $TAYLOR^{Q}$ and $TAYLOR^{\Delta B}$ subpar. Cost imposed on savers is severe enough to tilt the ranking of the planner. However, it turns out that consumption equivalents are extremely small and there are no noticeable differences between various policies. In fact, the difference between the best and the worst amounts to just 0.01pp. Next, we consider the preference shock. Results of this experiment are shown in Table 8. This scenario strongly favors $TAYLOR^{Q}$ and $TAYLOR^{\Delta B}$. With the exception of $TAYLOR^{\Delta Q}$ for the savers, LTV rules are always dominated and should not be used. We now proceed to the case when the only active shock is the financial shock. Results are presented in Table 9. In this case the ranking of the planner exactly matches the one of the borrowers. There is no agreement between the savers and the borrowers. Their rankings are reverse. It is this case where it is most clearly visible that the Pareto weight we are using favors the borrowers.

Before we conclude this section we want to discuss several aspects of our policy experiments. There are some limitations of our analysis which might impinge on the applicability of our findings. First, we consider a closed economy. Understanding international financial linkages, capital flows and effects of exchange rate shocks is crucial in economies featuring a significant level of openness. Second, we model fiscal policy in a very simplified way. Provision of public debt as well as sovereign default risk and its effect on balance sheets of banks would possibly call for different policy instruments and could affect the regime welfare rankings. Bocola (2016) shows that sovereign default risk was important in Italy during the period we consider. Third, our

[6] Since we are using approximation around the risky steady state (and not deterministic steady state), which is specific to each scenario, these scenarios imply different policy functions.

patient agents are fully rational and can easily smooth consumption. Analyzing some form of bounded rationality or perhaps hand-to-mouth behavior resulting from borrowing constraint could also affect our findings. The most likely effect would be an increase in the marginal propensity to consume. The aggregate demand channel would feature more prominently and could possibly allow us to match the observed cyclical pattern of inflation better. It would affect the way in which monetary policy works.[7] The last remark is related to the lack of the housing market. This most likely understates benefits of using LTV ratio as a macroprudential tool.

5.3 Central bank loss function and tradeoff between output and inflation stabilization

We are also interested in studying which regime would be chosen by the policy maker aiming at stabilizing inflation and output (i.e. central bank with the standard ad-hoc loss function):

$$LOSS_t = var(\Pi_t) + \kappa var(\Upsilon_t)$$

The relative weight placed on these two components of the loss function is given by κ. We consider two values, $\kappa = 0.1$ and $\kappa = 1$. The first one describes the situation in which the central bank is hawkish and is mainly concerned with inflation stabilization, the second one in which it is more dovish and cares equally about inflation stabilization and output stabilization. Note that we focus on the stabilization of output, not output gap (understood as deviation from the level of output which would prevail in an economy with flexible prices and wages). *Output* stabilization might actually lead to welfare losses, for example when fluctuations in output are driven by productivity shocks. Thus there is no reason to think that the loss function we are using represents preferences of a benevolent planner trying to maximize social welfare.

[7] See discussion of monetary policy transmission channels in Two- and Heterogeneous Agent New Keynesian Models in Kaplan et al. (2018).

There are three reasons why we decided against focusing on the output gap. First, it is difficult to observe. Second, as discussed in Kiley (2013), the usual natural-rate approach defines the gap as one that would arise in the absence of nominal rigidities and shocks to markups; this approach is motivated in simple New Keynesian models by their particular structure - nominal rigidities are the only (significant) distortion. Our model features frictional financial intermediation. It is not clear whether the collateral constraint should be treated as the feature of "technology" allowing to transfer funds between two types of agents or as a distortion, for example resulting from moral hazard. The same concern applies to financial shocks in our model. Therefore focus on flexible-price output does not have be directly related to economic efficiency. The third reason is that there are no grounds to expect that second order approximation of social welfare function would admit representation directly related to variances of inflation and output gap.[8]

The resulting values of the loss function are presented in Table 10. The policymaker that takes into account only these two variables will always choose $TAYLOR^{Q}$. Coincidentally, this is exactly the same rule that maximizes social welfare. When capital prices do not move much, fluctuations in the degree to which the collateral constraint is binding are muted. This allows the borrowers to maintain a similar level of consumption without having to reduce investment drastically. As a consequence, volatility of output will be reduced. The superiority of this rule is even more profound if we consider a more dovish policymaker. It indicates that this policy rule is especially potent when the policy maker is more interested in stabilizing output than inflation. Almost all other policies, both interest rate and LTV, are worse than the baseline monetary policy rule. There is only one exception - $TAYLOR^{\Delta B}$ results in a somewhat smaller loss when $\kappa = 1$. It suggests that this rule works mostly through stabilizing output rather than inflation.

[8] Suppose $\lambda = 1$. The planner would try to stabilize C^e, possibly at the cost of extreme fluctuations in consumption and labor supply of savers.

6 Conclusion

In this paper we try to answer whether monetary policy responding to financial variables outperforms a separate macroprudential authority using LTV ratio as its instrument. Two natural criteria arise as means of such a comparison: 1) stability of inflation and output and 2) welfare of two types of agents present in our model. Welfare of impatient agents is highest under the monetary policy rule that responds to deviations of capital prices from their steady state level. Patient agents prefer debt stabilization. Weights in the social welfare function typically employed in the literature tend to favor the impatient agents and suggest that monetary policy reacting to deviations of capital prices should be adopted. Our analysis suggests that LTV ratio has limited usefulness.

We calculate the value of the standard ad-hoc loss function of the central bank and conclude that the rule responding to deviations of capital prices from the steady state level would be chosen by an authority that is preoccupied with stabilizing output and inflation. LTV policies are never first best under our baseline calibration.

A natural avenue for further research is to explore efficiency of macroprudential policy in a model with richer heterogeneity. This would also allow us to understand distributional consequences of stabilizing asset prices and credit growth and the role that macroprudential policy plays in shaping wealth inequality. An example of framework suitable for such an analysis is Kaplan et al. (2018).

7 References

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Table 1: Calibration - parameters

Parameter	Description	Value
β	Discount factor for patient agents	0.995
β_e	Discount factor for impatient agents	0.97
δ	Capital depreciation rate	0.025
θ	Inverse of intertemporal elasticity of substitution in consumption	2
φ	Inverse of Frisch elasticity of labor supply	2
h	Degree of external habit formation in consumption	0.8
Ψ_P	Calvo probability for prices	0.7
Ψ_W	Calvo probability for wages	0.9
ϕ_p	Elasticity of substitution between various types of intermediate goods	6
ϕ_w	Elasticity of substitution between various types of labor	6
Ξp	Indexation parameter for prices	0.5
Ξw	Indexation parameter for wages	0.5
χX	Investment adjustment cost	10
α	Elasticity of output with respect to capital	0.35
ϕ_B	Elasticity of substitution between various types of loan contracts	203
δ^B	Depreciation ratio of bank capital	0.0466
ω^{reg}	Target bank capital to loans ratio	0.1
$\omega^{penalty}$	Curvature of capital requirement penalty function	10
div	Share of bank profits paid out as dividends	0.15
γ_R	Interest rate smoothing in Taylor rule	0.85
γ_M	LTV ratio persistence	0.71
γ_Π	Response to inflation in Taylor rule	1.50
γ_Y	Response to output gap in Taylor rule	0.15
Π	Steady state inflation	1.0025
m	Steady state LTV ratio	0.35
g	Share of gov. purchases in output	0.21

Table 2: Calibration - stochastic processes

Parameter	Description	Value
ρ_Z	Productivity shock - autocorrelation	0.95
σ_Z	Productivity shock - standard deviation	0.0008
ρ_υ	Preference shock - autocorrelation	0.88
σ_υ	Preference shock - standard deviation	0.0080
ρ_ζ	Investment specific shock - autocorrelation	0.93
σ_ζ	Investment specific shock - standard deviation	0.0020
ρ_μ	Financial shock - autocorrelation	0.81
σ_μ	Financial shock - standard deviation	0.0009
σ_R	Interest rate shock - standard deviation	0.0004
σ_m	LTV ratio shock - standard deviation	0.0040

Table 3: Steady state

Ratio	Value
Spread - annualized	0.020
Investment to output	0.18
Capital to output (annualized)	1.80
Consumption to output	0.61
Debt to output (annualized)	0.60
Banks capital to loans	0.1
Consumption of impatient agents to total consumption	0.24

Table 4: Baseline model - stochastic properties

Variable	St. dev. (%)		Autocorrelation		Correlation with output	
	Model	Data	Model	Data	Model	Data
Output	0.43	0.48	0.94	0.89	-	-
Total consumption	0.37	0.29	0.95	0.90	0.80	0.80
Investment	1.15	1.15	0.97	0.78	0.75	0.86
Loans	0.56	2.83	0.93	0.96	0.18	-0.03
Spread	1.20	1.16	0.81	0.65	-0.45	-0.50
Inflation	0.40	0.88	0.89	0.88	-0.11	0.51

All variables are quarterly euro area (19 countries fixed composition) for 1999-2019. We use real gross domestic product as output, real final consumption expenditure as total consumption, real gross fixed capital formation as investment, quarterly change in HICP as inflation. These series come from Eurostat. MFI loans to non-financial corporations (outstanding amounts at the end of period, total maturity), deflated by HICP are used as loans. ECB SDW is the source of this data. Data on MFI interest rates on loans to non-financial corporations (new business, total maturity) is from Eurostat. Trending variables are expressed as log-deviations from Hodrick-Prescott trend component

Table 5: Variance decomposition

Variable\Shock	**Productivity**	**Preference**	**Investment specific**	**Financial**	**Interest rate**	**LTV**
Total consumption	7.25	65.88	4.93	10.86	10.03	1.06
Output	5.05	31.60	7.30	34.65	19.84	1.56
Investment	1.83	0.58	7.07	69.89	19.50	1.14
Loans	14.82	5.84	19.24	42.85	14.82	5.67
Real capital prices	2.61	1.49	9.68	56.71	17.07	12.44
Retail interest rate	12.87	7.87	3.75	65.17	10.24	0.10
Inflation	53.68	8.98	10.18	19.26	7.59	0.32

Table 6: All shocks - welfare ranking and consumption equivalents

Policy	**Borrowers**		**Savers**		**Representative**	
	Rank	**Eq.**	**Rank**	**Eq.**	**Rank**	**Eq.**
Baseline	7	2.2268	3	2.0896	6	2.1964
$TAYLOR^{\Delta B}$	3	1.5811	1	0.1629	2	1.2534
$TAYLOR^{Q}$	1	0.4456	2	1.6346	1	0.7321
$TAYLOR^{\Delta Q}$	6	2.1640	7	3.1663	7	2.3946
$LTV\Delta B$	4	1.7669	5	2.4311	4	1.9176
LTV^{Q}	2	1.5586	6	2.5333	3	1.7878
$LTV\Delta Q$	5	2.1468	4	2.2574	5	2.1715

Table 7: Productivity shock - ranking

Policy	Savers	Borrowers	Representative
Baseline	2	4	2
$TAYLOR^{\Delta B}$	7	2	7
$TAYLOR^{Q}$	6	1	4
$TAYLOR^{\Delta Q}$	5	3	1
$LTV\Delta B$	4	7	3
LTV^{Q}	1	6	5
$LTV\Delta Q$	2	5	3

Table 8: Preference shock - ranking

Policy	Savers	Borrowers	Representative
Baseline	3	7	6
$TAYLOR^{\Delta B}$	1	3	2
$TAYLOR^{Q}$	2	1	1
$TAYLOR^{\Delta Q}$	7	5	3
$LTV\Delta B$	5	4	7
LTV^{Q}	6	2	5
$LTV\Delta Q$	4	6	4

Table 9: Financial shock - ranking

Policy	Savers	Borrowers	Representative
Baseline	2	6	6
$TAYLOR^{\Delta B}$	5	3	3
$TAYLOR^{Q}$	7	1	1
$TAYLOR^{\Delta Q}$	4	4	4
$LTV\Delta B$	1	7	7
LTV^{Q}	6	2	2
$LTV\Delta Q$	3	5	5

Table 10: Loss function of the central bank (x100)

Policy	**κ = 0.1**	**κ = 1**
Baseline	0.1029	0.29
$TAYLOR^{\Delta B}$	0.1083	0.24
$TAYLOR^{Q}$	0.0281	0.06
$TAYLOR^{\Delta Q}$	0.1206	0.33
$LTV\Delta B$	0.1059	0.30
LTV^{Q}	0.1080	0.29
$LTV\Delta Q$	0.1070	0.30