Macroprudential and Monetary Policies with an Imperfectly Competitive Banking Sector

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Abstract

This paper studies the effect of bank competition on the optimal use of monetary and macroprudential policies. I first present empirical evidence documenting the dampening impact that banks' market power has on the transmission of monetary policy in the United States. To study the policy implications of these findings, I develop a New Keynesian DSGE model with collateral constraints and an imperfect competitive banking sector. The results from the model demonstrate that the degree of competition in the banking sector has a sizable impact on the optimal mix of monetary and macroprudential policies. Specifically, the gains from a leaning-against-the-wind monetary policy are substantially smaller when the banking sector is less competitive. Results suggest that from a policy perspective, monitoring the level of bank competition is crucial when the objective is to promote financial and economic stability.

Keywords: Monetary policy, Macroprudential policy, DSGE models, Financial frictions, Financial stability, Banking competition

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1 Introduction

The recent financial crisis has lead to a re-examination of how policymakers should deal with unsustainable credit booms. Recent studies have documented that credit growth and household leverage are highly significant predictors of financial crises and crisis severity (Mian and Sufi 2010a; Mian and Sufi 2010b; Schularick and Taylor 2012; Olsen 2015). This evidence has led to the view that financial regulations should incorporate a macroprudential dimension. The general idea is that regulation should aim to make the financial sector as a whole more resilient to shocks and try to prevent build-ups of systemic risk (Borio 2011). However, the appropriate implementation of these new regulation policies, as well as the level of coordination with monetary policy, remains an open question. One specific debate is over the role that monetary policy should take in mitigating financial vulnerability. On the one hand, some point to the limitations of macroprudential tools and the lack of conclusive empirical evidence regarding their effectiveness to suggest that monetary policy should be used to "lean against" buildups of financial vulnerability (Woodford 2012; Stein 2014; Adrian and Liang 2016). On the other hand, others argue that there should be a clear separation between the two tools and that monetary policy should not include financial stability objectives (Svensson 2016).

The goal of this paper is to contribute to the debate about the optimal mix of monetary policy and macroprudential tools by investigating the extent to which banks' market power shapes the effectiveness and optimal implementation of the two instruments. This paper is motivated by the recent decline in the intensity of bank competition worldwide and the growing evidence for the general failure of perfect competition in the banking sector (Claessens 2009; Clerides, Delis, and Kokas 2015). Recent empirical studies also show that the degree of competition in the financial sector matters for monetary transmission (Adams and Amel 2011; Brissimis, Delis, and Iosifidi 2014; Drechsler, Savov, and Schnabl 2017) and for the supply of credit (Rice and Strahan 2010; Favara and Imbs 2015; Liebersohn 2017). Thus, banks' market power could potentially play a relevant role in mitigating the adverse effects of unsustainable credit booms. However, to the best of my knowledge, most studies which try to assess the effectiveness and optimal implementation of macroprudential and monetary tools have not considered bank competition.

The paper is also motivated by a parallel inconclusive debate over the connection between bank competition and financial instability.[1] Despite the inconclusive evidence, policymakers

[1] The two contradicting views are known as the *competition-fragility* and *competition-stability* perspectives. See

have expressed a general belief that a trade-off exists between competition in the banking sector and financial stability.[2] Vives (2016) argues that policymakers can mitigate the competition-stability trade-off by coordinating competition policy with the newly-proposed prudential policies. However, to the best of my knowledge, there is little research on how financial competition interacts with macroprudential tools. Thus, it remains an open question whether financial competition should be taken into consideration when using monetary policy and macroprudential tools to promote financial stability.

Given this background, the paper proceeds in two parts: First, I use aggregate U.S. state-level data to empirically explore the role that banks' market power play in the transmission of monetary policy. Using the local projection method proposed by Jordà (2005), I examine the response of state-level output, total bank lending and house prices to monetary policy shocks. Results show that the response to monetary shocks is significantly stronger in states where the banking sector is relatively more competitive. These results suggest that different levels of bank competition can significantly shape the transmission of monetary policy and should, therefore, be taken into consideration when conducting monetary policy.

To formally test this last claim, I develop a New Keynesian dynamic stochastic general equilibrium (DSGE) model with financial frictions in the form of an imperfectly competitive banking sector based on the framework of Andrés, Arce, and Thomas (2013) (hereafter AAT). A key feature of AAT model is that loan spreads are set endogenously by profit-maximizing banks. I simplify and extend AAT framework in a number of ways. First, I relax the assumption of efficient risk-sharing between households and entrepreneurs and eliminate from the model any lump-sum aggregate subsidies and taxes. AAT use this assumption to approximate welfare using a utility-based loss measure in the spirit of Benigno and Woodford (2012). I use the more parsimonious approach which assumes that the central bank wishes to minimize a quadratic loss function which includes the unconditional variance of inflation, output, and a financial

Zigraiova and Havranek (2016) for a review of the conflicting evidence.

[2] For example, in the U.S., Federal Reserve Governor Tarullo (2012) stated that according to the Dodd-Frank Act the pursuit of financial stability might cause a trade-off with other desirable economic aims such as financial competition. In Israel, when presenting the Bank of Israel's philosophy regarding the desired model of competition in the Israeli financial sector, Governor Flug (2016) stated that "The aim is to achieve the proper balance between the two [competition in the banking system and financial stability], and this is a constant challenge." In the U.K., while the promotion of competition is one of the regulation authority objectives, it is secondary to the primary goal which is maintaining stability (Bank of England 2015), suggesting the two objectives may sometimes be at odds.

stability target.[3] Second, I extend the model by adding a "leaning against the wind" (LATW) monetary authority and a countercyclical macroprudential rule.

The model is used to (i) quantify how imperfect competition in the banking sector shapes the aggregate response of the economy to technology and a housing demand shock, and (ii) investigate what banking competition implies for the optimal implementation of monetary and macroprudential policies. The simulation results suggest that an optimal mix of macroprudential regulation and monetary policy could benefit from taking into account the intensity of banks' competition. Specifically, the choice of optimized policy parameters, as well as the optimal combination of monetary and macroprudential policies, depends on the level of banks' market power. Additionally, the result demonstrates that in some cases, an imperfectly competitive banking sector can promote stability, supporting the idea that there is a competition-stability trade-off. The results also show that when supply-side shocks drive the dynamics of the economy, policymakers can use countercyclical prudential policies to reduce economic instability while also benefiting from a more competitive banking sector.

From a policy point of view, this research is important because it investigates the extent to which policymakers should monitor levels of bank competition when using monetary and macroprudential policies to boost macroeconomic and financial stability. According to the estimates shown in this paper, the recent global decrease in bank competition may reduce the effectiveness of monetary policy transmission and potentially change the optimal policy reaction to economic and financial conditions. The results are in line with recent research which stresses the importance of accounting for the structure of the banking system when conducting monetary and regulatory policies (Corbae and Levine 2018). This line of research is especially relevant given the recent rise in bank concentration in the U.S. and worldwide.

The paper proceeds as follows: Section 2 reviews related literature. Section 3 discusses the time series empirical evidence. Sections 4 and 5 present the theoretical model and the simulation results. In Section 6 I compare the performance of different policy regimes. Section 7 concludes.

[3] See Section 6.2 for a discussion about the choice of welfare criterion.

2 Related Literature

This paper fits with several strands of the literature which incorporate financial frictions in macroeconomic models. First, this paper is closely related to research which adds banks' market power to the New Keynesian framework that features financial frictions in the form of collateral constraints, originating from Kiyotaki, Moore, et al. (1997). The model used in this paper is most closely related to Andrés and Arce (2012) and Andrés, Arce, and Thomas (2013), who use the Salop (1979) spatial model to model imperfect competition in the banking sector. In their model, loan spreads are set endogenously by dividend maximizing banks.[4] An alternative way to model bank market power in a New Keynesian DSGE framework is taken by Gerali et al. (2010) and Güntner (2011), who use interest rate adjustment costs and monopolistic competition in the banking sector using a Dixit-Stiglitz framework. The main reason that I chose to use AAT framework is that it allows for an endogenously-derived credit spread which fits some of the key empirical facts regarding price-cost margins in the financial system.[5]

Second, this paper is related to a large body of research which studies the coordination and implementation of monetary and macroprudential policies in the context of DSGE models. The first group of papers shows that depending on the type of shock, a combination of countercyclical macroprudential rules and a LATW monetary policy may improve welfare (Kannan, Rabanal, and Scott 2012; Angeloni and Faia 2013; Angelini, Neri, and Panetta 2014; Bailliu, Meh, and Zhang 2015). On the other hand, Gelain, Lansing, and Mendicinoc (2013) find that LATW monetary policy can reduce the volatility of some variables at the cost of increasing inflation volatility, which may cause a policy trade-off. Tayler and Zilberman (2016) and Collard et al. (2017) take this point a step further by showing that countercyclical prudential policy can improve welfare while also eliminating the need for a financially augmented monetary policy rule.[6]

The above literature typically assumes that the banking sector is either perfectly competitive

[4] A similar approach is used by Olivero (2010), who also uses a version of the Salop (1979) circular city model to model market power for international banks.

[5] See Section 5.2 for a discussion on the model properties.

[6] Other notable contributions that embed financial frictions in a DSGE model when analyzing optimal monetary and macroprudential policy rules include (but are not limited to) Beau, Clerc, and Mojon (2012), Rubio (2014), Benes and Kumhof (2015), Rubio and Carrasco-Gallego (2016b), Gelain and Ilbas (2017), Kiley and Sim (2017), Kolasa (2016), and Alpanda and Zubairy (2017).

or does not incorporate a banking sector at all. A notable exception is the study of Angelini, Neri, and Panetta (2014) whose model features an imperfectly competitive banking sector in the spirit of Gerali et al. (2010). Angelini et al. treat monopolistic bank competition as a necessity to obtain a steady-state with bank capital different from zero, and do not consider how the level of bank market power itself can affect the results.[7] This paper is, therefore, the first to explicitly consider bank competition when studying the connection between monetary and macroprudential policies in a DSGE framework.

This paper is also related to the literature which studies the aggregate and policy implication of regional heterogeneity. Motivated by large imbalances between countries in the euro area, a number of studies use a two-region New Keynesian DSGE model to study the optimal implementation of monetary and macroprudential policies in a monetary union with heterogeneous members (Rubio 2014; Quinta and Rabanalb 2014; Brzoza-Brzezina, Kolasa, and Makarski 2015; Palek and Schwanebeck 2015; Rubio and Carrasco-Gallego 2016a; Bielecki et al. 2017; Dehmej and Gambacorta 2017). In contrast to these models which focus on the euro area, Beraja et al. (2017) build on the cross-sectional variation between U.S. states in the recent recession to study the relationship between monetary policy and regional asymmetries.[8] In these models, the sources of the cross-region heterogeneity are set by using asymmetric shocks, different proportion of borrowers, heterogeneous mortgage contract structures, differences in LTV ratio, and different leverage ratios. This study contributes to this literature by demonstrating the potential of using banks' market power as an important source of the regional variations.

On the empirical front, a number of studies have examined the connection between banks' market power and the transmission of monetary policy.

The first group of paper has focused on the traditional bank lending channel mechanism. According to the bank lending channel, monetary policy influences the supply of bank lending by affecting the quantity of banks reserves and core deposits. However, as noted by Romer et al. (1990), if banks have access to alternative sources of funds, their lending will be less sensitive to monetary policy shocks.The literature offers at least two opposing hypotheses regarding the impact of bank competition on the bank lending channel mechanism. First, banks that have

[7] Another notable paper which uses Gerali et al. (2010) set-up is Gambacorta and Signoretti (2014), who study whether monetary policy should take financial conditions into account. They also use the framework to obtain non-zero steady-state bank capital and do not include any prudential policy in their model.

[8] Midrigan and Philippon (2016) also use U.S. regional variation to investigate how liquidity constraints affect aggregate dynamics.

more market power may have more access to alternative funding sources and may, therefore, be less affected by policy changes. Second, increased competition may increase the market share held by larger banks who are in general less sensitive to monetary changes (Kashyap and Stein 2000). While the first hypothesis postulates that increased bank competition strengthens the impact of monetary policy through the bank lending channel, according to the second hypothesis it weakens it. The existing empirical evidence on the bank lending channel in the U.S. find that stronger bank competition intensifies the impact of monetary policy on the volume of bank lending, suggesting the first hypotheses dominates the second (Adams and Amel 2011; Brissimis, Delis, and Iosifidi 2014).[9]

Brissimis, Delis, and Iosifidi (2014) also examined the impact of bank competition on monetary transmission through the bank risk-taking channel. According to the risk-taking channel, monetary policy may impact banks' risk-taking behavior, specifically willingness to supply riskier loans (Borio and Zhu 2012). For example, low policy rates may induce banks to "reach for yield" and supply riskier loans to meet high expected rates of return. However, a less competitive banking system may lead to greater banks profits which will reduce banks incentive to engage in hazardous activities. Thus, an increase in banks' market power may mitigate the impact of monetary policy through the risk-taking channel.

Recently, a new channel has been proposed which examines deposits spreads as a potentially important link between bank competition and monetary transmission Drechsler, Savov, and Schnabl (2017). The so-called deposit channel postulates that when the federal funds rate rises, banks widen the interest spreads they charge on deposits which reduce the quantity of available funds and induces a contraction in lending. The channel is stronger when banks have more market power over deposits. Therefore, higher levels of banks' market power increase the transmission of monetary policy through the deposit channel. Drechsler, Savov, and Schnabl (2017) show that in the U.S. banks in high-concentration areas react more aggressively following a change in the federal funds rate, suggesting that monetary policy has a greater economic impact when the banking sector is less competitive.

[9] Similar results are found for the Euro area by Leroy (2014) and Fungáčová, Solanko, and Weill (2014) and by Amidu and Wolfe (2013) for a panel of 978 banks from 55 countries. However, contradicting evidence was found by Olivero, Li, and Jeon (2011) for a panel of Asian and Latin American countries and mixed evidence by Khan, Ahmad, and Gee (2016) using bank-level data from five Asian countries.

3 Time Series Evidence

Given the contradicting mechanisms presented in the previous section, the aggregate implications of bank competition on the transmission of monetary policy remains an open question. In this section, I use the variation across states in the U.S. to test the impact that bank competition has on monetary policy effectiveness. Specifically, I estimate the response of key state-level variables such as output, house prices and total bank lending to monetary policy shocks using the local projection method proposed by Jordà (2005).

Local projection impulse responses are estimated by using a series of regressions over different horizons and using the coefficient on the shock as the impulse response estimate. Following Ramey and Zubairy (2018) I estimate a state-dependent local projection model which allows for different reactions to monetary shocks in states with high and low bank competition. In particular, a set of panel fixed effect regressions are estimated for each horizon h as follows:

$$\Delta \ln (Y)_{i,t+h} = \tau T_t + I_{i,t} \left[\alpha^L_{i,h} + \beta^L_h MP_{i,t} + \gamma^L_h X_{i,t-1}\right] + \\ (1 - I_{i,t}) \left[\alpha^H_{i,h} + \beta^H_h MP_{i,t} + \gamma^H_h X_{i,t-1}\right] + \varepsilon_{i,t+h} \quad (1)$$

where i and t denote states and time respectively. Y, the variable of interest, is either real GDP, House price index, or total bank lending. I is a dummy variable that indicates the level of bank competition in state i at year t. To measure state-level bank competition, I use the popular Lerner index which measures banks' market power by estimating banks' ability to charge a price markup over the marginal cost. The Lerner index ranges between 0 and 1, where larger values are interpreted as indicating more market power (less competition).[10] I equals one if the state-level Lerner index is at or above the cross-state median. Therefore, all coefficients vary according to whether the state is in state "L" (Low competition) or "H" (High competition). MP is the monetary policy shock, X is a vector of state-level controls, α_i is the state fixed effect, and T is a time trend.

Monetary policy shocks are identified using changes in the effective federal funds rate since it was the primary policy tool during the sample period.[11] X controls for state-specific demand factors and time-varying economic condition. The vector includes lagged values of the log

[10] Bank-level Lerner indexes are calculated following the code and data provided by Koetter, Kolari, and Spierdijk (2012). State-level Lerner is the weighted mean of the individual measures using the banks' deposits share as weights following Clerides, Delis, and Kokas (2015).

[11] The critical assumption is that since monetary policy is conducted nationally, the economic conditions of any

change in real income per capita, log change in population, and the change in the unemployment rate.[12] The baseline sample period for the analysis consists of annual state-level data from 1987-2007. The sample starts when the Fed began using interest rate targeting and stops before the recent financial crisis.[13]

Eq. (1) is estimated separately for each horizon. The impulse responses to a monetary policy shock are computed as a sequence of the coefficients β_h^L and β_h^H where the former represents the reaction in states with week bank competition and the latter with strong bank competition. Following Ramey and Zubairy (2018) 90 percent confidence interval are computed using Newey-West standard errors.

The results from estimating Eq. (1) are presented in Fig. 1. The figure plots the impulse response functions (IRFs) following the one percent contractionary change in the federal funds rate. The first column presents the cumulative change of real GDP, total bank lending and house prices in states with low competitive banking sector (dashed red lines) and highly competitive banking sector (solid blue lines). The figure also displays each IRF with the corresponding 90% confidence interval in the other two columns.

The results show that a contractionary monetary shock leads to a stronger and more significant reaction of all variables in states where the banking sector was more competitive. The results suggest that bank competition plays a vital role in the transmission of monetary policy to the real economy. For example, real GDP in states with a more competitive banking sector will be around two percentage points lower relative to states were banks have more market power four years after the shock.

Recall from Section 2 that the literature suggests contradicting channels through which bank competition and monetary transmission interact. The aggregate results presented in this section suggest that during the sample period in the U.S., the channels through which bank competition amplified monetary shocks dominated the channels which dampens them.[14]

single state will not affect the policy rate. The federal funds rate can, therefore, be viewed as exogenous from the perspective of every single state (Driscoll 2004). For robustness, I alternatively use the Romer and Romer (2004) estimates of exogenous monetary policy shocks (see discussion below).

[12] See Appendix A.1 for data definitions and descriptive statistics.

[13] Another reason to start the sample in 1987 is that there was a break in some of the state-level measures due to a change in the Standard Industrial Classification (SIC) system.

[14] It should be noted that focusing on aggregate variables does not provide conclusive evidence on the quantitative importance of each channel through which bank competition may affect monetary transmission. This is an important extension that future research should address.

I conduct a number of tests to check the robustness of the results. A first concern is that the change in the federal funds rate is an imperfect measure of monetary shocks since it may be endogenous to national economic conditions that may be strongly correlated with the state-level conditions. A better measure is one which only captures unexpected exogenous monetary policy shocks. Therefore, as a first robustness test, I replace the changes in the federal funds rate with Romer and Romer (2004) estimates of exogenous monetary policy shocks.[15] Fig. 2 presents the results when using the alternative measure of monetary shocks. The results are in line with the results obtained when using changes in the federal funds rate.

Additionally, I check the robustness of the results to alternative specifications. Specifically, I add the following variables as additional controls: (i) one lag of each dependent variables and the monetary policy shocks, (ii) the log of the state level Herfindahl Hirshman index (HHI) to control for heterogeneity in banking concentration across states, (iii) the log changes of state-level inflation, and (iv) the log of real GDP per capita to control for convergence effects. The results are robust to the alternative specifications (available in the online supplemental appendix).

Overall, the empirical results point to the important role that bank competition may play when policymakers consider monetary policy. However, the results do not give a clear answer on how policymakers should adjust their optimal policy response given different levels of bank competition and more specifically the recent increase in banks' market power. Therefore, there is a need for a more general perspective of the interaction between bank competition, monetary policy, policymakers objectives and the real economy. In the next section, I address this issue by developing a model which captures some of the key features of the empirical evidence uncovered in this section. I then use the model to evaluate, from a normative perspective, what bank competition imply for setting optimal policy.

[15] I obtained the Romer and Romer (2004) measure from Barakchian and Crowe (2010) who extend the measure through 2008. I thank Barakchian and Crowe for making the measure available. For each year, I sum the quarterly shocks to obtain an annual measure.

4 Model

4.1 Model setup

The starting modeling framework is an infinite-horizon, discrete-time, New Keynesian model, following Andrés, Arce, and Thomas (2013) (AAT). AAT studied how adding imperfect competition into a DSGE model with financial frictions *à* la Iacoviello (2005) affects the optimal implementation of monetary policy. I develop a simplified version of AAT model and extend it to study how banks' market power affects the interaction between monetary policy and macroprudential rules, and whether monetary policy should respond to financial imbalances.

The model features the following agents: (i) a measure one of infinitely lived households, (ii) a measure one of infinitely lived entrepreneurs, (iii) a continuum of monopolistically competitive final goods firms that transform a homogeneous intermediate good produced by the entrepreneurs into a differentiated final good of verity $z \in (0,1)$, (iv) a fixed number of $n > 2$ monopolistically competitive commercial banks, (v) a monetary authority that sets the nominal interest rate, and (vi) a regulator (macroprudential) authority that sets banks' required loan-to-value ratio (LTV).

The model features financial frictions in the form of collateral constraints following Kiyotaki, Moore, et al. (1997). As is standard in this class of models, there is a housing market where housing is used as a durable good which enters households utility function and is also used as collateral when borrowing from banks. Following Iacoviello (2015), I assume that the supply of housing is fixed and that its price varies endogenously. The allocation of housing between patient and impatient household is determined by the model.

The following subsections describe the objectives and constraints faced by each type of agent.

4.2 Households

Households choose consumption, housing, and work hours to maximize a lifetime utility function subject to a budget constraint.[16] Assuming all households are identical, the representative household maximizes:

[16] The budget constraint is expressed in real terms.

$$E_0 \sum_{t=0}^{\infty} \beta^t (\log c_t - \frac{(l_t^s)^{1+\varphi}}{1+\varphi} + j_t \log h_t) \tag{2}$$

s.t. :

$$d_t + c_t + q_t(h_t - h_{t-1}) = div_t + f_t + w_t l_t^s + \frac{R_{t-1}^D d_{t-1}}{\pi_t} \tag{3}$$

where c_t, h_t and l_t^s represent consumption goods, housing stock, and hours of work supplied by household at time t. β is the patient household discount factor. $\frac{1}{\varphi}$ is the Frisch labor supply elasticity. j_t is the weight of housing in the utility function. As in Rubio and Carrasco-Gallego (2016a), I assume that $log(j_t) = log(j) + e_{j,t}$, where j is the steady-state value of the weight on housing in the utility, $e_{j,t} = \rho_j \log(e_{j,t-1}) + u_{j,t}$ and $u_{j,t} \sim N(0, \sigma_j^2)$ is an i.i.d shock to housing preference. d_t is bank deposits in real terms at the end of period t. q_t is the real housing price. f_t and div_t are lump-sum profits received from final goods firms and banks respectivly, both are assumed to be owned by households (both in real terms). w_t is the real wag rate. R_{t-1}^D is the riskless nominal return on deposits between period $t-1$ and t.[17] Finally, $\pi_t \equiv \frac{P_t}{P_{t-1}}$ is the gross inflation rate.

The first order conditions for housing, labor, and consumption are:

$$\beta \mathrm{E}_t \left[\frac{q_{t+1}}{c_{t+1}} \right] + \frac{j}{h_t} = \frac{q_t}{c_t} \tag{4}$$

$$w_t = c_t (l_t^s)^{\varphi} \tag{5}$$

$$\frac{1}{c_t} = \beta R_t^D \mathrm{E}_t \left[\frac{1}{c_{t+1} \pi_{t+1}} \right] \tag{6}$$

4.3 Entrepreneurs

Entrepreneurs use real estate and household labor to produce an intermediate good y_t that they sell to final goods producers in a perfectly competitive market at a price P_t^I. Assuming a Cobb-Douglas constant return to scale production function:[18]

$$y_t = A_t (l_t^d)^{1-\alpha} (h_{t-1})^{\alpha} \tag{7}$$

[17] Following Iacoviello (2005), I assume that debt contracts are set in nominal terms and are not indexed to inflation.

[18] I assume a continuum of entrepreneurs of mass 1, indexed by k. Symmetry across firms and flexible prices allows me to write the production of y_t without the index k.

where A_t is the technology parameter that follows an autoregressive process:

$$\log A_t = \rho_A \log(A_{t-1}) + u_{A,t} \tag{8}$$

and $u_{A,t} \sim N(0, \sigma_A^2)$ is an i.i.d shock to technology.

As in AAT, I assume entrepreneurs draw utility only from consumption goods and suffer utility loss from traveling to a bank to obtain a loan. The utility loss is denoted by $\kappa\delta^{k,i}$, where $\delta^{k,i}$ is the distance between entrepreneur k to bank i at time t and κ is the utility cost per distance units. A representative entrepreneur thus maximizes:

$$E_0 \sum_{t=0}^{\infty} (\beta^e)^t (\log c_t^e - \kappa \delta_t^{k,i}) \tag{9}$$

s.t. :

$$c_t^e + q_t(h_t^e - h_{t-1}^e) + \frac{R_{t-1}^B b_{t-1}}{\pi_t} = \frac{y_t}{x_t} - w_t l_t^d + b_t \tag{10}$$

$$b_t \leq m_t \mathrm{E}_t \left[\frac{q_{t+1} h_t^e \pi_{t+1}}{R_t^B} \right] \tag{11}$$

Eq. (10) is the entrepreneurs' budget constraint, where b_t is the real value of one period nominal loans and R_{t-1}^B is the nominal loan rate between period $t-1$ and t. x_t is the price markup of final goods over intermediate goods, which is equal to $\frac{P_t}{P_t^I}$, where P_t is the final good price index and P_t^I is the nominal price of the intermediate goods. Thus, $\frac{1}{x_t}$ is the real price of the intermediate goods (or the marginal cost of the final goods). c_t^e, h_t^e and l_t^d represent consumption goods, housing stock, and hours of work demanded by entrepreneurs at time t, respectively.

β^e is the entrepreneurs' discount factor, with $\beta^e < \beta$. Following Kiyotaki, Moore, et al. (1997), entrepreneurs face collateral constraint on the amount they can borrow each period, which is expressed by Eq. (11). That is, borrowers cannot borrow more than a fraction m_t of the expected value of their real estate stock. Thus, m_t could be interpreted as the loan-to-value ratio. As shown by Iacoviello (2005), assuming that borrowers discount the future more relative to households guarantees that the borrowing constraint is binding in the area of the steady state. An important distinction in this model with respect to AAT is that in AAT the LTV ratio follows an exogenous autoregressive process.[19] Here, on the other hand, a regulator controls the LTV ratio, which adds macroprudential policy to the model (see Section 4.6.1).

[19] Others, such as Iacoviello (2005), use a fixed LTV ratio.

The first order conditions for the entrepreneur are:

$$w_t = \frac{y_t(1-\alpha)}{x_t l_t^d} \tag{12}$$

$$\frac{1}{c_t^e} = \beta^e R_t^B \mathrm{E}_t \left[\frac{1}{c_{t+1}^e \pi_{t+1}}\right] + \lambda_t^e \tag{13}$$

$$\frac{q_t}{c_t^e} = \mathrm{E}_t \frac{\beta^e}{c_{t+1}^e}\left[\frac{y_{t+1}\alpha}{x_{t+1}h_t^e} + q_{t+1}\right] + \lambda_t^e m_t \mathrm{E}_t \left[\frac{\pi_{t+1}q_{t+1}}{R_t^B}\right] \tag{14}$$

where λ_t^e is the Lagrange multiplier on the borrowing constraint. In this setting, it is possible to show that in every period entrepreneurs consume a constant fraction, equal to $(1-\beta^e)$, from their real net wort denoted by nw_t^e:[20]

$$c_t^e = (1-\beta^e) nw_t^e \tag{15}$$

where nw_t^e is defined as:

$$nw_t^e \equiv \frac{y_t}{x_t} + q_t h_{t-1}^e - \frac{R_{t-1}^B b_{t-1}}{\pi_t} - w_t l_t^d \tag{16}$$

That is, in every period t, entrepreneurs' real net worth is equal to the real income from production plus the real value of housing stock at the beginning of the period minus costs of labor and loan payment.

4.4 Final goods firms

There is a continuum of monopolistically competitive final goods firms of mass 1, indexed by z, which are owned by patient households. Final goods firms buy the intermediate good y_t in a perfectly competitive market at price P_t^I. They turn the intermediate good to a final good $y_t^f(z)$ at no cost and sell them at a markup x_t. Each final good firm z sells their good $y_t^f(z)$ at price $P_t(z)$. The aggregate final output index is then a composite of the individual final goods:

$$y_t^f = \left[\int_0^1 y_t^f(z)^{\frac{\varepsilon-1}{\varepsilon}} dz\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{17}$$

where $\varepsilon > 1$ is the elasticity of substitution in consumers preference. The demand for final good z is then given by:

$$y_t^f(z) = \left(\frac{P_t(z)}{P_t}\right)^{-\varepsilon} y_t^f \tag{18}$$

[20] See derivation in Appendix B.1.

and the price index is given by:

$$P_t = \left[\int_0^1 P_t(z)^{1-\varepsilon} dz \right]^{\frac{1}{1-\varepsilon}} \tag{19}$$

To add nominal price rigidities, I assume a Calvo pricing system, where in each period there is a probability of $1-\theta$ for each final goods firm to set price optimally. When the final goods firm is able to set prices optimally, it maximizes the future value of all profits in the expected period that it can't change the price:

$$E_t \sum_{i=0}^{\infty} (\theta\beta)^i \frac{c_t}{c_{t+i}} \left[\left(\frac{P_t(z)}{P_{t+i}} - mc_{t+i} \right) y_t^f(z) \right] \tag{20}$$

$$\tag{21}$$

where mc_t is the firms' real marginal cost (identical across all firms) which is equal to $\frac{P_t^I}{P_t}$ or the inverse of the markup, x_t. Using $\frac{1}{x_t}$ as the real marginal cost, Eq. (18), and letting P_t^* be the optimal price chosen by all firms who are able to adjust at time t (in equilibrium all firms who adjust their price face the same demand and thus choose the same price), the first order condition of the maximization problem with respect to P_t^* is:

$$P_t^* = \frac{\varepsilon}{\varepsilon - 1} \frac{E_t \sum_{i=0}^{\infty} (\theta\beta)^i \frac{1}{c_{t+i}} \frac{1}{x_{t+i}} y_{t+i}^f \left(\frac{1}{P_{t+i}} \right)^{-\varepsilon}}{E_t \sum_{i=0}^{\infty} (\theta\beta)^i \frac{1}{c_{t+i}} y_{t+i}^f \left(\frac{1}{P_{t+i}} \right)^{1-\varepsilon}} \tag{22}$$

The aggregate price level then satisfies:

$$P_t = \left[\theta P_{t-1}^{1-\varepsilon} + (1-\theta)(P_t^*)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} \tag{23}$$

Using Eq. (22), Eq. (23), and log-linearizing, I obtain the standard forward-looking New Keynesian Phillips curve:

$$\hat{\pi}_t = \beta E_t \hat{\pi_{t+1}} - \psi \hat{x}_t \tag{24}$$

where hated variables denote percent deviations from the steady state and $\psi = (1-\theta)(1-\beta\theta)/\theta$. Eq. (24) shows that inflation is positively related to future inflation and negatively related to the markup (inverse of the marginal cost).

Total real profits in the final goods sector are equal to:

$$f_t = \int_0^1 \left(1 - \frac{P_t^I}{P_t(z)}\right) y_t^f(z)dz$$
$$= (1 - 1/x_t)y_t^f$$

which are transferred to the households.

4.5 Banks

Assume credit is available only through $n > 2$ banks, indexed by i, and owned by households. Households supply funds (deposits) that pay a nominal gross rate R_t^D. Banks are perfectly competitive in the deposit market, and take the deposit rate (set by the central bank) as given. Banks make loans to entrepreneurs and charge a gross nominal rate of R_t^B.

To model banks' market power, the model uses a circular-city model *à la* Salop (1979). In this setup, a fixed number of n banks are located symmetrically on a circumference of unit one, where entrepreneurs are distributed uniformly.[21] Bank $i \in 1, 2, \cdots, n$ then chooses $R_t^B(i)$ to maximize:

$$E_t \sum_{\tau=0}^{\infty} \beta^\tau \frac{c_t}{c_{t+\tau}} div(i)_{t+\tau} \tag{25}$$

s.t. :

$$div(i)_t + \frac{R_{t-1}^D d_{t-1}(i)}{\pi_t} + b_t(i) = \frac{R_{t-1}^B(i) b_{t-1}(i)}{\pi_t} + d_t(i) \tag{26}$$

$$d_t(i) = b_t(i) \tag{27}$$

where $\beta^\tau \frac{c_t}{c_{t+\tau}}$ is the stochastic discount factor of the households at time $t+\tau$ and $div(i)_t$ are the bank's profits in real terms. Eq. (26) is the banker flow of funds constraint (in real terms), and Eq. (27) is the balance sheet identity so that Eq. (26) can be reduced to:

$$div(i)_t = \left(R_{t-1}^B(i) - R_{t-1}^D\right) \frac{b_{t-1}(i)}{\pi_t} \tag{28}$$

[21] Following AAT, I assume that an individual entrepreneur's location changes every period according to an *i.i.d* stochastic process in order to eliminate strategic interaction between specific banks and specific borrowers.

Following AAT, one can express each bank's loan volume $b_t(i)$ as $b_t(i)^k b_t(i)^*$, where $b_t(i)^k$ is entrepreneur k demand for funds from bank i (size of the loan) and $b_t(i)^*$ is bank i market share (measure of entrepreneurs that borrow from bank i). Maximizing the banker problem with respect to $R_t^B(i)$ then gives:

$$R_t^B(i) = R_t^D + \frac{1}{-\frac{\partial b_t^k(i)}{\partial R_t^B(i)} \frac{1}{b_t^k(i)} - \frac{\partial b_t^*(i)}{\partial R_t^B(i)} \frac{1}{b_t^*(i)}} \tag{29}$$

From Eq. (29) we can see that the spread between the lending and the deposit rate is a function of the bank's market power, which depends on the bank's loans size and market share. In a symmetric equilibrium where all banks set the same R_t^B, the optimal interest rate margin is:[22]

$$R_t^B - R_t^D = \frac{R_t^D - m_t E_t \left(\pi_{t+1} \frac{q_{t+1}}{q_t} \right)}{\eta m_t E_t \left(\pi_{t+1} \frac{q_{t+1}}{q_t} \right) - R_t^D} R_t^D \tag{30}$$

where

$$\eta = 1 + \frac{n}{\kappa} \frac{\beta^e}{1 - \beta^e} \tag{31}$$

The degree of banking competition is captured by the ratio of $\frac{n}{\kappa}$, with a lower ratio representing less competition. The ratio can be interpenetrated as representing two realistic sources of banks' market power. First, banks can derive market power from their closeness to the borrowing firm due to transportation cost advantages (Degryse and Ongena 2005). Thus, the concentration of lending institutions in a given area can be the first source of market power. In the model, the concentration of banks is captured by n, the number of banks in the model. As n increases, the ratio $\frac{n}{\kappa}$ also rises which represents an increase in competition and a decrease in the loan spread. The second source of banks' market power is the real costs that borrowers must pay if they wish to switch lenders. The existence of these costs can be explained by long-term relationships, repeated contracts, fixed technical costs, and informational asymmetries.[23] Switching costs can create a "lock-in" effect that reduces borrowers' switching incentives and

[22] See full derivation in Appendix B.2.

[23] There is well-established literature documenting that the costs of switching lenders are an important source of market power in the banking sector. See for example Kim, Kliger, and Vale (2003), Santos and Winton (2008), and Egarius and Weill (2016), among others.

increases banks' ability to charge higher prices. In the model, switching costs are captured by κ, which represents the ease at which an entrepreneur can switch banks. When κ increases, it represents a reduction in the switching costs, which reduces banks' market power.

From Eq. (30) we can see that in this setup, the lending spread is decreasing in the level of bank competition. This feature of the model is supported by ample evidence for the negative relationship between banks' market power and lending spreads (Degryse and Ongena 2008; Van Leuvensteijn et al. 2013). Additionally, the lending spread is also decreasing in the LTV ratio (m_t) and the expected increase in housing prices, $E_t\left(\pi_{t+1}\frac{q_{t+1}}{q_t}\right)$, which is in line with the balance sheet channel of monetary policy, where an increase in asset price increases borrowers borrowing ability.

4.6 Regulation and Monetary Policy

My central extension to the AAT model is adding a regulator which sets the LTV ratio according to a defined policy objective. Additionally, I consider two types of monetary policy regime: one that follows a standard Taylor rule and a second policy regime where the central bank also reacts to changes in credit.

4.6.1 Macroprudential Policy

Modeling macroprudential policies is problematic since systemic risk, which is usually considered the main targeting objective for regulators, is not clearly defined and/or measured in most models. Recent studies suggests that large credit expansions tend to lead to financial crises (Drehmann, Borio, and Tsatsaronis 2011; Bakker et al. 2012; Schularick and Taylor 2012; Babecký et al. 2012). In line with this evidence, the Basel III committee proposed that credit to GDP should be used as the main reference variable for setting countercyclical capital buffers. Following this line, the regulator in this model reacts to signs of future financial imbalances, which are proxied by deviations of credit from its steady-state value. Following Rubio and Carrasco-Gallego (2014), I assume the regulator sets the LTV ratio based on a Taylor-type countercyclical rule:

$$m_t = m\left(\frac{b_t}{b}\right)^{-\phi_m} \tag{32}$$

where m is a steady state value for the loan-to-value ratio, b is the steady state level of debt, and ϕ_m is a measure of the responsiveness of the loan-to-value deviation of credit from steady-state levels. In this framework, the macroprudential authority "leans against" periods of credit expansion by setting a lower LTV ratio.

4.6.2 Monetary Policy

I assume a central bank which sets nominal interest rates, R_t^D, following a simple Taylor rule that responds to deviations in inflation and output from their steady state:

$$\frac{R_t}{R_{ss}} = \left(\frac{R_{t-1}}{R}\right)^{\phi_R} \left(\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi} \left(\frac{Y_t}{Y}\right)^{\phi_Y}\right)^{1-\phi_R} e^{u_{R,t}} \tag{33}$$

where R, π, Y are steady state interest rate, inflation and output. ϕ_R, ϕ_π, ϕ_Y are policy response coefficients and $u_{R,t} \sim N(0, \sigma_R^2)$ is i.i.d monetary policy shock.

4.6.3 Leaning Against the Wind (LATW) Monetary Policy

To add financial considerations into monetary policy, I will alternatively consider a central bank which follows an "augmented" Taylor rule. In this setup the central banks leans against build-ups of financial imbalances by changing the policy interest rate in response to deviations of credit from its steady-state value:

$$\frac{R_t}{R_{ss}} = \left(\frac{R_{t-1}}{R}\right)^{\phi_R} \left(\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi} \left(\frac{Y_t}{Y}\right)^{\phi_Y} \left(\frac{b_t}{b}\right)^{\phi_b}\right)^{1-\phi_R} e^{u_{R,t}} \tag{34}$$

4.7 Equilibrium

An equilibrium is defined as a collection of prices $\{w_t, P_t, q_t, P_t^*, x_t, R_t^D, R_t^B\}$ and quantities $\{y_t, c_t, c_t^e, f_t, div_t, h_t, h_t^e, l_t, d_t, b_t\}$ that for some exogenous process $\{u_{A,t}, u_{j,t}, u_{R,t}\}$ all agents in the model solve their maximization problem and the following market clearing conditions hold:

- In the good market, total supply of the intermediate good equals the total demand from the final good producers, which equals total demand for consumption good such that:

$$y_t = \int_0^1 \left(\frac{P_t(z)}{P_t}\right)^{-\varepsilon} dz \, y_t^f = c_t + c_t^e \tag{35}$$

- In the labor market demand for household labor equals supply.

$$l_t^s = l_t^d \tag{36}$$

- In the real estate market the total supply of housing which is fixed and normalized to unity equals demand for housing by households and entrepreneurs:

$$1 = h_t + h_t^e \tag{37}$$

- In the financial market the total supply of funds by households is equal to the total demand by entrepreneurs:

$$b_t = d_t \tag{38}$$

The full system of equations for the non-stochastic steady is presented in Appendix C.1.

5 Simulation Results

5.1 Solution and calibration

The model is solved by log-linearizing the equilibrium equations around a non-stochastic steady state with zero inflation. Appendix C.2 contains the full model in log-linear form. To parameterize the model, I set most of the model parameters, autocorrelation and standard deviation of the shocks following the mean of the posterior distribution estimated by Iacoviello and Neri (2010). The household discount factor is set as $\beta = 0.9925$ which implies an annual interest rate of 3% in steady state. Entrepreneurs' discount rate is set as $\beta^e = 0.97$, which implies that households are net savers and entrepreneurs are net borrowers in the steady state and its neighborhood.[24] The steady state weight on housing in the utility, j, the inverse of the Frisch elasticity, φ, the share of housing in the production, α, and the steady-state LTV ratio, m, are set at 0.12, 0.51, 0.05, 0.85 respectively.[25] The elasticity of substitution across goods, ε, is set at 7.76 which implies a markup of 1.15. The probability of not adjusting prices (Calvo parameter) is set at 83%. The autocorrelation and standard deviation of the technology shock and housing demand shock are set to $\rho_A = 0.95$, $\rho_j = 0.96$,$\sigma_A = 0.01$ and $\sigma_j = 0.0416$. All the parameters are summarized in Table 2.

A key non-standard feature of the calibration is the ratio n/κ which determines the steady state lending spread and is used as a proxy for the level of banks' market power. I compare two different levels of banks' market power. First, I consider an environment where banks have no

[24] See Iacoviello (2005) for a discussion.

[25] Iacoviello and Neri (2010) do not estimate the share of housing in the production which I, therefore, parametrize following Iacoviello (2005).

market power such that $R^D = R^B$ (i.e. $\kappa = 0$ and/or $n \to \infty$). Then, I consider a situation where banks have some level of monopolistic power. To calibrate the level of banks' market power, I follow Christiano, Motto, and Rostagno (2007) who showed that loan spreads in the U.S. from 1987 to 2003 were typically in the range of 200-298 basis points. For the case of an imperfectly competitive banking sector, I set the ratio n/κ equal to 0.7845 so that in steady state, the annual loan spread will equal 3%, the upper range implied by the data.[26]

5.2 Benchmark model properties

I check the performance of the benchmark model, i.e., standard Taylor rule without macroprudential policy. To illustrate the broad properties of the model, I use impulse response functions (IRFs) to examine whether the response to a monetary shock, under different levels of bank competition, is qualitatively similar to the empirical studies.[27]

For the baseline simulation, I fix the policy coefficients in the monetary policy reaction function following Justiniano, Primiceri, and Tambalotti (2015). The smoothing parameter, ϕ_R, the policy reaction to output, ϕ_Y, and the policy reaction to inflation, ϕ_π, are set at 0.8, 0.125, 2 respectively. According to Justiniano et al., these policy coefficients are in line with empirical estimations of the Tyler rule in the U.S. after 1984.

Figure 3 presents the impulse response functions of key variables to a one standard deviation contractionary monetary policy shock. An unanticipated increase in the deposit rate, R^D, induces a drop in output, prices, consumption (households and entrepreneurs), and overall debt. The response of all variables to the monetary shock is weaker when banks have more market power. The simulation results are therefore in line with the empirical evidence presented in Section 3 which documented that imperfect competition in the banking system dampens the pass-through of monetary policy. The IRFs are also qualitatively in line with the results presented in Andrés and Arce (2012) who use a similar version of the model.

The moderating effect of weaker competition in the banking system arises from the presence of two contradicting forces: countercyclical response of lending spreads and collateral effects. On the one hand, under imperfect competition, lending spreads react countercyclically which amplifies the impact of the shock. On the other hand, lower levels of bank competition keep loan

[26] This level of loan spread is also in line with other papers which include loan spread in a DSGE framework. See for example Curdia and Woodford (2010), Gerali et al. (2010), and Gambacorta and Signoretti (2014).

[27] Since the model is too stylized to reproduce the main features of the data such as second moments and autocorrelations, I evaluate the performance of the model qualitatively.

margins higher, which decreases entrepreneurs' borrowing and leverage ratio in the steady state. This, in turn, weakens entrepreneurs' responsiveness to fluctuations in the value of collateral, which dampens the effectiveness of policy changes. A stronger collateral effect relative to the lending spread effect can explain the overall weaker reaction to the policy shock when the banking sector is imperfectly competitive.

The benchmark model also features countercyclical lending spreads, in line with empirical studies. Empirical estimations for the U.S. documented that the contemporaneous correlation between banks' lending spreads and the U.S. GDP ranges between $-.2$ to -0.5 (Aliaga-Díaz and Olivero 2011; Corbae, D'erasmo, et al. 2011). Here, the benchmark model with an imperfect competitive banking sector and the baseline calibration generates a correlation between the loan spread and output of -0.6354. While the model overstates the countercyclicality of the lending margin quantitatively, the qualitative results are in line with the empirical estimates in the literature. Overall, the model can qualitatively capture some of the critical differences between an economy with a perfect versus an imperfectly competitive banking sector.

6 Comparing Policy Regimes

In this section, I investigate if the level of banks' competition affects the behavior of the estimated economy under the three different policy regimes described in Section 4.6. I consider two kinds of shocks: a technology (supply) shock and a housing preference (demand) shock. The reason for studying technology shocks are twofold. First, in the DSGE literature supply shocks are considered one of the most important sources of business cycle fluctuations during "normal times" (Angelini, Neri, and Panetta 2014). Second, supply-side shocks can cause an output-inflation trade-off for policymakers. If the degree of competition in the banking sector has a sizable impact on households leverage and the pass-through of monetary policy, imperfect competition in the banking sector can either alleviate or mitigate the output-inflation trade-off faced by the central bank. This, in turn, can impact the desirability of using monetary policy to stabilize the economy. I also analyze a housing demand shock, since recent literature has documented the significant role that the shock has played in the recent crisis and in driving credit boom-bust cycles (Iacoviello and Neri 2010; Iacoviello 2015).

6.1 Impulse response analysis

To illustrate how banks' market power may affect the optimal use of monetary and macroprudential policies, I start by examining the dynamic responses of the model economy to the two shocks. For each shock, I first examine the dynamic response under the three policy regimes: Benchmark (i.e., only standard Taylor rule), Macroprudential (i.e., standard Taylor rule with countercyclical LTV rule) and Macroprudential with LATW monetary policy (i.e., augmented Taylor rule with countercyclical LTV rule).[28] In the second step, I discuss the differences between an economy with a perfect and an imperfect competitive banking sector.

Throughout this subsection, the policy coefficients in the Taylor rule are set according to the baseline calibration described in Section 5.1. The policy coefficient on debt in the macroprudential policy rule and in the augmented Taylor rule are set to $\phi_m = 0.3$ and $\phi_b = 0.3$ following the calibration used by Kannan, Rabanal, and Scott (2012).

6.1.1 Technology shock

Figure 4 presents the dynamic response of selected key variables following a positive technology shock. The figure reports the reactions under the Benchmark policy regime (blue line), Macroprudential policy regime (red line), and Macroprudential + LATW policy regime (green line). Additionally, for each policy regime, the figure presents the response under perfect and imperfect competition (solid and dashed lines, respectively).

As expected, in all policy regimes, the increase in productivity induces an increase in output and house prices. The increase in collateral value also increases entrepreneurs' borrowing ability and the amount of debt. Inflation, on the other hand, declines following the supply shock, as is standard in New-Keynesian models. Thus, the three regimes yield qualitatively similar results. However, the magnitude of the dynamic response, as well as the policy reaction, are different across policy regimes.

In all three cases, the central bank reduces the policy rate to accommodate the fall in inflation. However, relative to the benchmark policy regime, when policymakers also use a countercyclical macroprudential rule to stabilize credit growth, they can promote price stability

[28] I do not consider a policy regime where the central bank uses LATW monetary policy without macroprudential policy. There is a consensus in the literature that macroprudential policies should be the first "line of defense" when dealing with build-ups of financial instability. The primary debate is whether monetary policy should also be used to complement the macroprudential tools (Mester 2017).

while also reducing the extent to which they need to use expansionary monetary policy. This suggests that macroprudential regulation can mitigate the impact of a technological shock on output, debt, and house price, which in turn can reduce the trade-off between output and inflation stabilization faced by policymakers.

On the other hand, under the macroprudential + LATW policy rule, the decline in inflation is more significant relative to the two other policy options which also induce a more accommodating policy rate. The economic intuition for the stronger fall in inflation under LATW monetary policy is as follows: when the central bank follows an augmented Taylor rule, forward-looking agents expect the central bank to be less accommodating to the shock because of the credit growth. Entrepreneurs then consider the potential relative higher policy interest rate (and the cost of credit), and the increase in the demand for credit and housing diminishes. As a result, housing prices increase by a smaller magnitude and borrowers' financing conditions improve significantly less, which in turn reduces production and induces a fall in prices.

Figure 4 thus highlights an important stability-economic activity trade-off that may arise after aggregate supply shocks. On the one hand, a policy regime with financially-augmented monetary policy rules can reduce debt, asset prices and output volatility which can perhaps promote financial stability. On the other hand, the expected aggressive response to credit expansion amplifies the volatility of inflation and increases the output-inflation trade-off.

Regarding the difference between a perfect and imperfect competitive banking sector, the responses of output, inflation and house prices are relatively similar across the two levels of bank competition and in all three policy regimes. However, in the benchmark regime and to a smaller extent in the macroprudential policy regime, the impact of the technology shock on total debt is dampened when the banking sector is imperfectly competitive. Thus, an imperfectly competitive banking sector may mitigate the potential gains from using monetary and macroprudential tools to deal with the boom.

6.1.2 Housing demand shock

I next consider the case in which the economy is hit by a positive housing demand shock, defined as an exogenous increase in the weight on housing in households utility.

First, I consider the model with perfect competition in the banking sector. As shown in Fig. 5, in the benchmark case (blue line), a positive housing demand shock which affects the marginal rate of substitution between consumption and housing leads to an increase in housing prices. The increase in the value of collateral increases entrepreneurs' borrowing ability who, being impatient, increase borrowing and use the extra available funds to finance consumption and housing (since the amount of housing is fixed, this implies households sell houses to the entrepreneurs). Entrepreneurs' demand for more consumption generates an economic expansion and increase in output. Additionally, the increase in the amount of housing used in production increases the marginal productivity of labor and real wages (not reported). This wealth effect allows households to reduce labor hours, which reduces the marginal cost of production. As a result, the inflation rate falls, driving the policy rate down. Thus, in the benchmark model with the baseline parameters, a positive housing demand shock is analogous to a positive technology shock.[29]

As in the case of a technology shock, when policymakers use macroprudential policy, the credit booms generated by the increase in the value of housing induces a decrease in the LTV ratio, mitigating the credit increase. The main differences between the reaction to the technology and housing demand shocks happen when policymakers also add credit consideration to their monetary policy rule (Macroprudential + LATW regime). Despite the expected policy response, the binding collateral constraint induces entrepreneurs to increase borrowing, reflecting the favorable borrowing conditions. This, in turn, generates an increase in the nominal policy rate that suppresses borrowing, output, and inflation.

The dynamics under the three simple rules when the banking system is imperfectly competitive are similar to the perfect competition case. As before, imperfect competition mitigates the effect of the shock on debt and output in the benchmark and macroprudential policy regime. However, imperfect competition in the banking sector generates a stronger reaction of housing prices relative to the perfectly competitive case. This could be explained by the lower effectiveness of the policy reaction when banks have market power. That is, given the source of the shock, policymakers ability to affect house price is limited when the banking sector is imperfectly competitive, and therefore, changes in the policy rate are less effective.

[29] The fall in inflation following the shock seems to contradict other estimated DSGE models with housing and financial frictions which find that a housing price shock tends to generate inflation (Kannan, Rabanal, and Scott 2012; Rubio and Carrasco-Gallego 2014). However, as shown by empirical studies, credit booms are generally *not* associated with a substantial increase in inflation (Mendoza and Terrones 2012). The deflationary effect of a positive housing demand shock is also consistent with Notarpietro and Siviero (2015), who use a New Keynesian model with a housing sector and collateral constrained borrowers to show that, with a social-welfare-maximizing monetary policy rule, a positive housing demand shock will induce a fall in inflation.

To summarize, the results are consistent with the idea that adding countercyclical macroprudential policy can improve stability following both a demand side and a supply side shock. Also compatible with much of the literature, the desirability of including financial considerations to a standard monetary policy rule is ambiguous since they tend to generate a trade-off between stabilizing total debt and other macro variables. The IRFs also demonstrate the vital role that banks' market power may play in choosing the optimal policy regime. On the one hand, an imperfectly competitive banking system can be stabilizing for overall debt volatility, which may reduce the attractiveness of adding debt to the policy reaction. On the other hand, banks' market power reduces policymakers' ability to affect some of the macro variables in the economy. I comment on this issue below, by adding an explicit policy objective.

6.2 Optimal policy analysis

The previous section documented that bank competition can affect the quantitative differences between policy regimes. However, the simulation results may depend on the values of the policy rules parameters. Additionally, it is not clear how bank competition may impact the optimal combination of monetary and macroprudential policies. Thus, in this subsection I investigate two questions: (i) How would the policy parameters in an optimal policy rule change given different levels of competition in the banking sector, and (ii) What does the level of banks' market power imply for the optimal combination of monetary and macroprudential tools.

To answer these questions, I assume the central bank's objective is to minimize a standard quadratic loss function which includes the variability of inflation, output, and total debt:

$$Loss = Var(\pi) + \zeta_y Var(y) + \zeta_b Var(b) \tag{39}$$

where $Var(\pi)$, $Var(y)$ and $Var(b)$ are the unconditional variances of inflation, output and borrowing. ζ_y and ζ_b are the weights that policymakers assign to stabilizing output and debt.[30] Using a standard quadratic loss function to represent policymakers' objective follows a large body of related research which uses a similar framework.[31] Adding the variance of debt to

[30] The weight on the inflation target is normalized to one; hence the weights on the output gap and debt are relative weights.

[31] See for example Kannan, Rabanal, and Scott (2012), Gelain, Lansing, and Mendicinoc (2013), Gambacorta and Signoretti (2014), Angelini, Neri, and Panetta (2014), Brzoza-Brzezina, Kolasa, and Makarski (2015), and Gelain and Ilbas (2017) amongst others.

the loss function follows Angelini, Neri, and Panetta (2014) and represents the objectives of the regulator and a LATW central bank. Assuming one loss function for both policymakers (regulator and central banker) represents the case in which the monetary authority and the macroprudential authority act in a coordinated way. An alternative, non-coordinated scheme is one in which the macroprudential regulator and the central bank each minimize their loss function while taking the other policy rule as given. An interpretation of the joint loss function (the coordinated scheme) is one in which the central bank mandate expends to macroprudential objectives and can use either the policy rate or a prudential rule to achieve its objectives.

It is important to note that since this loss function is not microfounded, it is subject to the Lucas Critique. However, despite its ad hoc nature, the quadratic loss function has the advantage of being a realistic representation to central bankers' typical mandate (Verona, Martins, and Drumond 2017). Also, the corresponding loss function may be a good parsimonious approximation to general social welfare (Debortoli et al. 2017).

To find the combination of coefficients that minimizes the loss function, I use grid-search conducted over the following ranges: $1.1 < \phi_\pi \leq 3$, $0 \leq \phi_Y$;ϕ_m ;$\phi_b \leq 2$.[32] Since policymakers' preferences can differ considerably across economies and over time, I consider a range of weights in the policy loss function. The weight on the output gap (ζ_y) varies in the following set of values $\{0.25, 0.5, 1\}$. These values are consistent with the weights that are typically considered in the literature.[33] The wight on the variance of debt (ζ_b) is kept fixed at 0.25 following Gelain, Lansing, and Mendicinoc (2013). Policymakers preference for stabilizing debt is hard to pin down given the limited evidence in the literature. To assess the robustness of the results I also consider the following wights on the variance of debt: $\{0.1, 0.5, 1\}$. These weights are in line with the alternative values used in the literature when adding financial concerns to a standard loss function.[34] The results and general conclusions when using these alternative values are consistent with the baseline estimation of the loss function and.[35]

For each combination of shock, policy regime, loss function and level of banks' competition,

[32] The smoothing parameter ϕ_R in the Taylor rule is kept fixed at 0.8. Applying limits to a grid search for policy parameters is common in the literature and is intended to keep the policy coefficients at a plausible range (Schmitt-Grohé and Uribe 2007). The grid step is 0.1 for all the coefficients.

[33] See Yellen (2012), Ilbas (2012), and Debortoli et al. (2017) for empirical estimations and suggestions of these three values.

[34] See for example gelain2013house, Angelini, Neri, and Panetta (2014), Rubio (2016), and Verona, Martins, and Drumond (2017).

[35] The results when using the alternative values for ζ_b are reported in the online supplemental appendix.

I compute the optimal policy coefficient and the value of the loss function. The calibration of the shocks and the other parameters are kept as described in Table 2. Table 3 presents the simulation results. The table shows the optimal policy coefficients for each policy regime given different policy preferences and level of banking competition. The table also reports the estimated value of the minimum losses when the economy is subject to a technology shock (Panel A) and a housing demand shock (Panel B).

A number of noteworthy results emerge from the table. First, the level of bank competition seems to affect the value of the optimal policy parameters. For every policy regime, the set of optimal policy parameters $\{\phi_\pi, \phi_Y, \phi_m, \phi_b\}$ is different if the economy has a perfect or imperfect competitive banking sector.[36] This suggests that for the policymaker to set the policy reaction optimally, she must consider the level of banks' market power in the economy. Second, while macroprudential regulation can reduce the value of the loss function relative to the benchmark case across all specifications, the additional benefits of LATW monetary policy depend on the level of bank competition and the source of the shock. Following a technology shock, a debt augmented Taylor rule can complement the macroprudential regulation and further minimize the loss function in a perfectly competitive banking sector economy. However, when banks have some degree of market power, these benefits vanish. In some cases, even when the policymaker can use LATW monetary policy, the optimized value of the policy coefficient on debt in the augmented Taylor rule (ϕ_b) is set to zero, equivalent to using only macroprudential policy with a standard Taylor rule. Under a housing demand shock, the results are more consistent across levels of bank competition. In both the perfect and imperfect competitive banking sector, macroprudential improves stability and LATW monetary policy does not substantially reduce the loss function further.

The general conclusion drawn from these results is that the optimal policy regime may depend on the source of the shock, the policymaker preferences, *and* the level of bank competition. The explanation for the smaller social benefits from a LATW monetary policy when banks are imperfectly competitive is that monetary policy tends to be less effective as banks have more market power. Hence, policymakers have limited ability to use the nominal policy rate to stabilize the economy. Notwithstanding, the benefits from prudential regulation are much more significant when the economy is hit by a housing demand shock relative to the

[36] While some policy parameters are identical, the full set of parameters is almost never the same. The only exception is the Benchmark policy regime under a technology shock and $\zeta_y \in \{0.25, 0.5\}$ where the policy parameters are identical in the perfect and imperfect competitive economies.

technology shock. This result is consistent with Angelini, Neri, and Panetta (2014), who also find that while macroprudential policy can promote stability when the dynamics of the economy are mainly driven by financial shock, for supply shocks, macroprudential policies provide minor additional benefits.

To further illustrate how banks' market power can reduce the desirability of LATW monetary policy, I construct an efficiency policy frontier (Taylor curve). The curve represents the best possible trade-off between output and inflation that policymakers can achieve. More specifically, the policy frontier is obtained by using a grid over ζ_y and plotting the optimized variances of output and inflation for each wight.[37] Figure 6 shows the policy frontier for the macroprudential policy regime and the macroprudential + LATW policy regime under different levels of bank competition. Panel A presents the results after a technology shock and Panel B after a housing demand shock. In general, a policy frontier which is closer to the origin represents a better trade-off between stabilizing output and inflation, and is therefore considered more "efficient." The figure illustrates that a leaning against the wind central bank can increase policy efficiency only after a technology shock and if the banking sector is perfectly competitive. The results suggest that when the banking sector is imperfectly competitive, central banks cannot use the policy rate to produce a more stable economic system. However, if the banking sector is perfectly competitive the benefits of LATW depends on the source of the shock.

A final observation from Table 3 is that, in some cases, an imperfectly competitive banking sector can be stabilizing for the economy. After a technology shock, the total losses are equal or lower in the perfect competitive economy relative to an economy with an imperfectly competitive banking sector, across all policy regimes. However, when the source of the shock is housing demand, the values of the total losses are equal or *higher* in the perfect competitive economy. More specifically, under the benchmark policy regime, an imperfectly competitive banking sector increases stability across all loss function when the source of the model dynamics is a housing demand shock. To understand this last observation, it is helpful to analyze the impact of the housing demand shock on entrepreneurs' demand for consumption goods. As

[37] The grid step is 0.05, and the range for ζ_y is $[0.25, 1]$. To focus on the trade-off between output variability and inflation variability, ζ_b is set to zero when constructing the efficiency frontier. See Gambacorta and Signoretti (2014), Rubio and Carrasco-Gallego (2014), Brzoza-Brzezina, Kolasa, and Makarski (2015), and Brzoza-Brzezina, Kolasa, and Makarski (2017) for examples of using policy efficiency frontiers to evaluate the performance of LATW monetary policy and macroprudential tools.

shown in Eq. (16), entrepreneurs consume a constant fraction of their net worth. A housing demand shock impacts the economy mainly through entrepreneurs' ability to borrow and their demand for consumption. Since imperfect banking competition reduces borrowers' steady state net worth and ability to borrow, the impact of the shock and volatility is smaller relative to the perfectly competitive case. While the same mitigating mechanism works following a technology shock, the impact is smaller since the shock does not affect borrowers' net worth directly, but only through the indirect impact on housing prices. The stabilizing impact of banks' market power is therefore much stronger following a housing demand shock relative to the technology shock.

These results demonstrate the tension between two contradicting forces: On the one hand, an imperfectly competitive banking sector dampens the initial effect of the stochastic disturbance (supply and demand), and can, therefore, mitigate the loss function relative to a perfectly competitive economy. On the other hand, facing a perfectly competitive banking sector also implies more effective policy tools that increase policymakers' ability to stabilize the economy. Table 3 therefore illustrates that a critical question in analyzing the benefits of an imperfectly competitive banking sector is the nature of the shock hitting the economy and policymakers' ability to use macroprudential policies. A key conclusion from these results is that under the benchmark policy regime and a demand shock, an imperfectly competitive banking sector can promote stability for the economy. However, if policymakers can use countercyclical regulation tools, banks' market power does not increase stability for both supply and demand shocks.

7 Summary

This paper investigates the role of bank competition in the transmission and optimal use of monetary and macroprudential policies. Macro models which try to estimate the proper policy reaction to buildups of financial vulnerability have generally ignored the role of banks' market power in policy transmission.

I start by providing new empirical evidence on the link between bank competition and the transmission of U.S. monetary policy shocks. I do so by applying local projection methods to a panel of U.S. states and conditioning the reaction of GDP, total bank loans and house prices to a monetary shock on the level of bank competition in the state. The results demonstrate that a monetary shock tends to generate a stronger and more significant reaction in states where the banking sector is relatively more competitive. Therefore, the empirical evidence suggests that bank competition may matter for understanding the transmission of monetary policy and its optimal implementation.

To rational these results, I develop a DSGE model with an imperfectly competitive banking sector and use it to assess the normative implications of bank competition on using macroprudential and monetary policies. Using a baseline calibration, I show that following a monetary shock the model delivers impulse responses that are in line with the empirical evidence. Additionally, the correlation between lending margins and output in the model fits the evidence from empirical studies. The qualitative similarity between the model and the empirical evidence suggest that the model is suitable for conduction policy analysis. I then study the reaction to a technology and a housing demand shock when monetary and macroprudential policies change according to different rules and policy objectives. Using impulse response functions, I show that the level of competition in the financial system substantially affects the response of the economy to the shocks. Finally, I examine how bank competition can change the appropriate combination of monetary and macroprudential policies. In particular, I assume that policymakers' objective is to minimize a standard loss function which includes the variance of inflation, output, and debt. Considering a variety of loss functions, I show that the optimal policy reaction, as well as the benefits from using LATW monetary policy, depend on the level of bank competition. Specifically, the gains from LATW are substantially smaller when the banking sector is imperfectly competitive.

The policy lessons arising from the model are threefold. First, for policymakers to set policy parameters optimally, they must consider the level of competition in the banking sector. Second, while using macroprudential policy is always stabilizing for the economy, the advantages of a financially augmented Taylor rule are substantially smaller when the banking sector is imperfectly competitive relative to the perfectly competitive case. Finally, the results suggest that under certain conditions, specifically demand driven shocks and policymakers using suboptimal policy rules, some level of market power can be stabilizing for the economy. As noted by Dudley (2015), there may be substantial practical challenges in implementing macroprudential policies. The results presented here suggest that while using macroprudential policies can be the first best option, if those tools are not available, the economy may benefit from a less competitive banking sector that can promote stability and reduce the reaction to stochastic disturbances. Overall, the results highlight how considering financial conditions, specifically bank competition, can play a crucial role when policymakers use monetary and macroprudential policies to enhance economic stability.

A number of limitations and essential extensions should be acknowledged. First, by focusing primarily on the implication of bank competition on monetary transmission, the paper leaves aside other social benefits that may arise from a stronger or weaker banking competition. These benefits could include, for example, a more efficient banking system that can affect the cost of credit and the steady state level of consumption. Hence, it may be worthwhile to also consider agents' utility-based welfare as the policymaker objective to account for these additional implications. Second, in this paper, I have adopted a positive approach to bank competition by taking the level of bank market power as given and studying its effects on the optimal combination of monetary and macroprudential policies. However, in the real world policymakers may have some control over the level of bank competition through various competition policies.[38] Therefore, a natural extension of this paper would be to explore the implications of coordinating between bank competition, monetary and macroprudential policies. Finally, the evidence points to the importance of regional heterogeneous financial markets in the pass-through of monetary policy. An additional interesting extension will be to use a two-region (or more) monetary union model, where the regions differ in their level of bank competition. The model can then be used to study the level (regional or national) at which macroprudential policies should be conducted, and the level of coordination with monetary policy. These are important extensions which I leave for future work.

[38] For example, in the U.S. bank regulators can require merging banks to divest branches in areas where the merger causes anti-competitive concerns.

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A Empirical

A.1 Data and variables definition

Lerner index- Bank level Lerner index calculated following Koetter, Kolari, and Spierdijk (2012). State-level Lerner is the weighted mean of the bank individual measures, using the banks' deposits share as weights. The sample excludes the District of Columbia and South Dakota. The Lerner index ranges between 0 and 1, where larger values are interpreted as indicating more market power (less competition).

Total bank loans- Consistent year-end bank-level data from the Federal Reserve's Report of Condition and Income (Call Reports), made available from Drechsler, Savov, and Schnabl (2017). I use gross total loans and leases from series rcfd1400. Sample includes state insured (rssd9424 = 1, 2, 6 or 7) commercial banks (rssd9048 = 200). Exclude any bank-year observation in any year where the bank was involved in a merger (using the most recent merger file from the Federal Reserve Bank of Chicago). Use only banks with positive values for total assets and loans. Total loans are aggregated to the state level by summing across all commercial banks operating in a given state.

Real GDP- Real GDP by state (millions of chained 1997 dollars) published by the U.S. Bureau of Economic Analysis (BEA).

House Price Index- Annual average of the state level house price index, all-Transactions Indexes, published quarterly by Federal Housing Finance Agency (FHFA).

Personal income per capita- State level per capita personal income (thousands of dollars) published annually by the BEA.

Population- Annual state population, as estimated by the BEA.

Unemployment rate- State level unemployment rate, not seasonally adjusted, published annually by the Bureau of Labor Statistics (BLS).

Herfindahl Hirshman index (HHI)- The sum of squared banks' shares of the deposit market in each state. Banks' deposits from call report series rcfd2200. Call report data sample same as in total bank loans.

Inflation- Change in each state's Gross State Product (GSP) deflator. GSP deflators are measured using the annual nominal and real GDP measures published annually by the BEA.

FFR- Effective Federal Funds Rate, Percent, Annual , published by the Federal Reserve Economic Data in the Federal Reserve Bank of St. Louis (FRED).

Romer & Romer- Querterly Romer and Romer (2004) measure of monetary policy shocks from Barakchian and Crowe (2010). Annual measure is the sum of all shock from each quarter. Higher values indicate tighter monetary policy conditions.

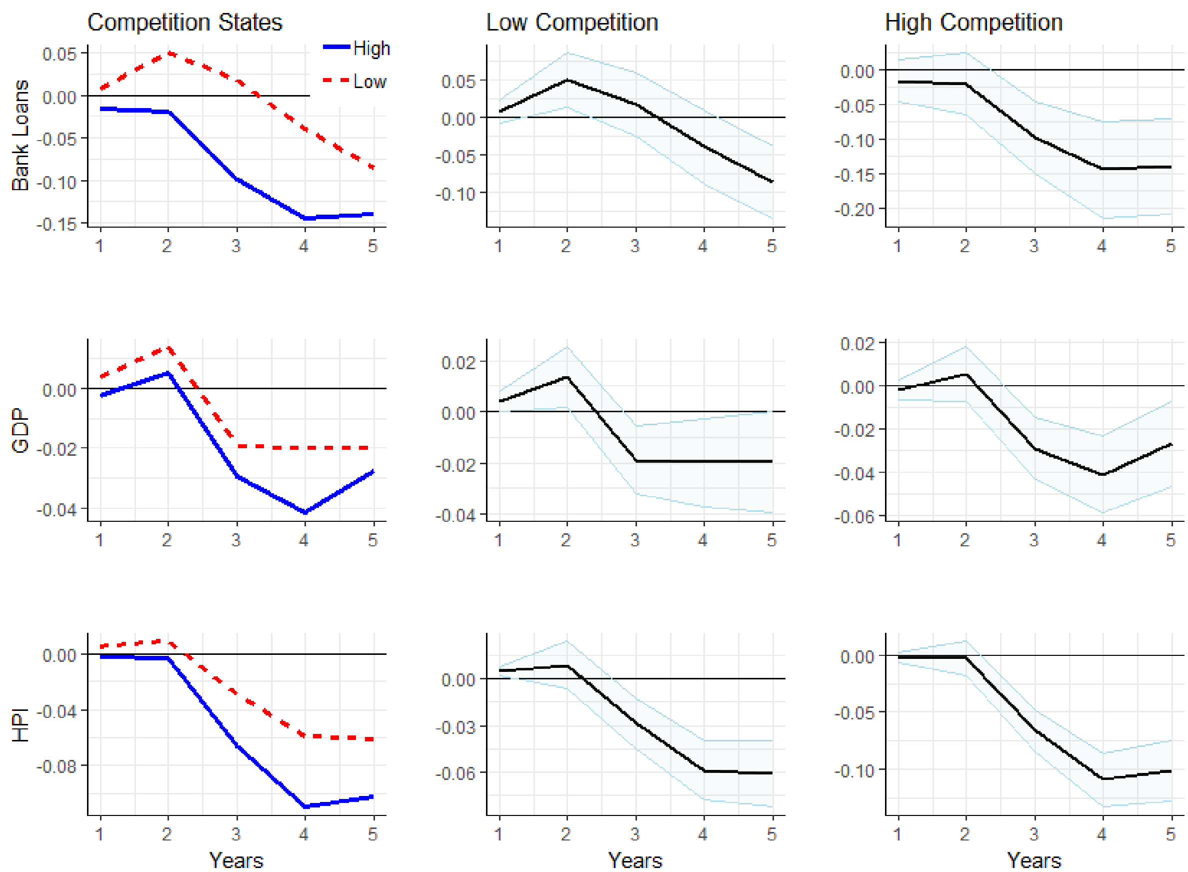
Table 1: Descriptive statistics

Statistic	Full Sample					Low Competition					High Competition				
	N	Mean	St. Dev.	Min	Max	N	Mean	St. Dev.	Min	Max	N	Mean	St. Dev.	Min	Max
Federal funds rate (%)	1,050	4.87	2.07	1.13	9.22										
Romer & Romer	1,050	0.29	0.77	−1.57	2.02										
Lerner	1,029	0.32	0.05	−0.07	0.45	504	0.35	0.03	0.28	0.45	525	0.29	0.05	−0.07	0.37
Real GDP (log)	1,050	10.41	0.32	9.65	11.17	504	10.37	0.33	9.65	11.15	525	10.45	0.31	9.75	11.17
House price index (log)	1,050	5.33	0.38	4.40	6.57	504	5.21	0.35	4.40	6.46	525	5.45	0.39	4.46	6.57
Total bank loans (log)	1,050	16.95	1.21	13.35	20.57	504	16.77	0.99	14.12	19.58	525	17.12	1.38	13.35	20.57
Personal income p.c. (log)	1,050	10.11	0.30	9.30	10.97	504	10.06	0.29	9.30	10.73	525	10.16	0.30	9.37	10.97
Population (log)	1,050	15.02	1.01	13.03	17.41	504	14.84	0.89	13.03	17.40	525	15.26	1.06	13.08	17.41
Unemployment rate (%)	1,050	5.18	1.47	2.30	12.10	504	5.07	1.47	2.30	11.30	525	5.35	1.44	2.30	12.10
GSP deflator (log)	1,050	−0.13	0.09	−0.45	0.07	504	−0.13	0.09	−0.45	0.07	525	−0.13	0.09	−0.43	0.00
HHI (log)	1,029	6.75	1.00	4.10	9.21	504	6.45	1.00	4.10	9.18	525	7.04	0.91	4.63	9.21
Δ Federal funds rate	1,000	−0.08	1.40	−2.41	1.86	480	−0.08	1.40	−2.41	1.86	500	−0.08	1.40	−2.41	1.86
Δ Real GDP	1,000	0.03	0.07	−0.14	0.41	480	0.04	0.07	−0.08	0.39	500	0.03	0.07	−0.14	0.41
Δ House price index	1,000	0.05	0.04	−0.12	0.26	480	0.05	0.04	−0.08	0.26	500	0.04	0.05	−0.12	0.23
Δ Total bank loans	1,000	0.04	0.46	−2.98	3.92	480	0.06	0.29	−1.70	1.94	500	0.03	0.56	−2.98	3.92
Δ Personal income p.c.	1,000	0.05	0.02	−0.07	0.13	480	0.05	0.02	−0.07	0.13	500	0.04	0.02	−0.01	0.11
Δ Population (%)	1,000	0.01	0.01	−0.06	0.07	480	0.01	0.01	−0.06	0.07	500	0.01	0.01	−0.01	0.05
Δ Unemployment rate	1,000	−0.09	0.68	−2.80	2.30	480	−0.13	0.58	−2.70	2.10	500	−0.06	0.77	−2.80	2.30
Inflation	1,000	0.01	0.07	−0.45	0.12	480	0.01	0.07	−0.45	0.12	500	0.01	0.06	−0.43	0.10

Notes: This table presents the descriptive statistics for the main variables used in Eq. (1) and the robustness tests. The sample period is 1987 - 2007. Columns 2-6 includes the full sample, columns 7-11 describe the sample of states with relative low bank competition and columns 12-16 for states with high bank competition. The divided sample includes all 50 states excluding South Dakota due to missing bank competition measure (Lerner index). Number of observations (N), mean, standard deviation, minimum and maximum of each variable are given.

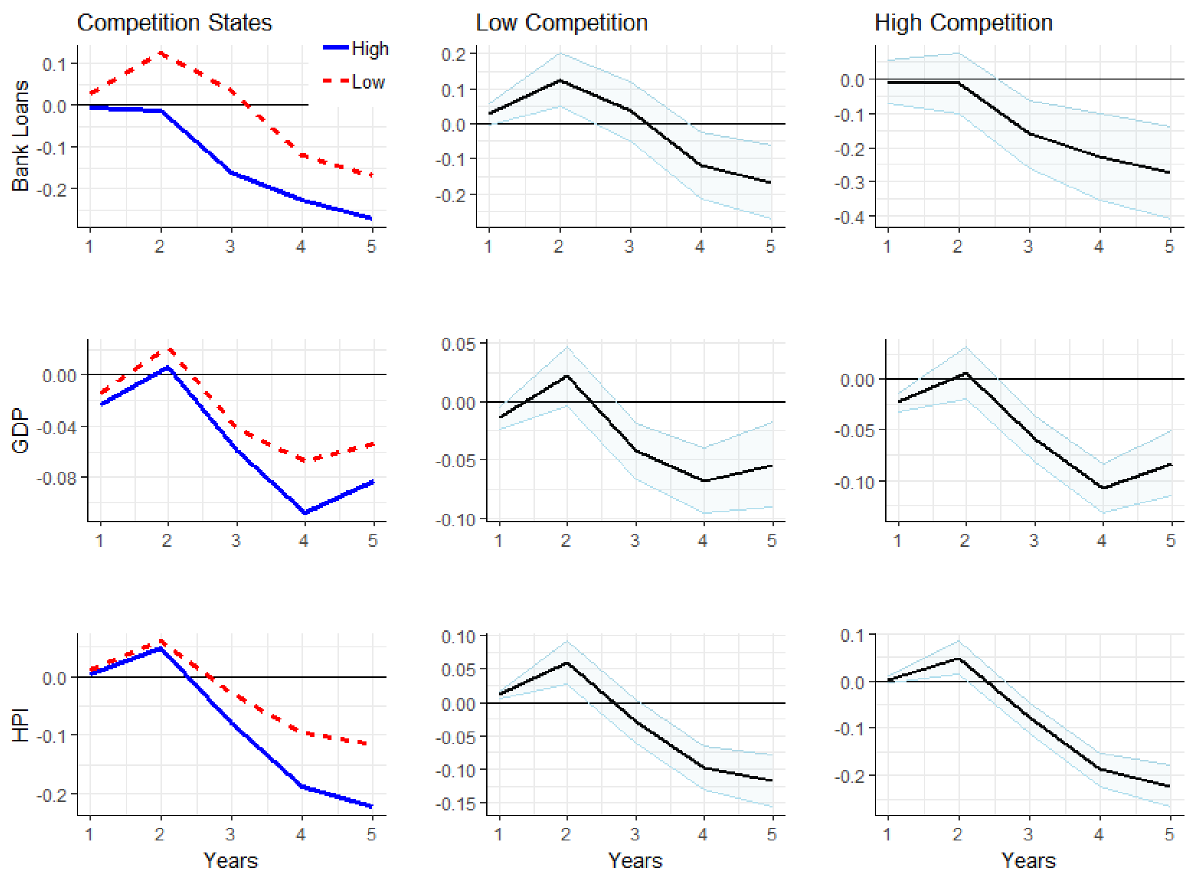
A.2 Empirical results and robustness

Figure 1: Bank competition and monetary policy shocks



Note: Impulse response to an increase in the effective federal funds rate of 100 basis points. The first column shows the responses in states with high (blue-solid line) and low (red-dashed line) bank competition. 2nd and 3rd columns show the responses with the associated 90% confidence bands calculated using Newey-West standard errors.

Figure 2: Robustness; alternative monetary policy shocks



Note: Impulse response to an unanticipated increase in monetary policy rates of 100 basis points measure following Romer and Romer (2004). The first column shows the responses in states with high (blue-solid line) and low (red-dashed line) bank competition. 2nd and 3rd columns show the responses with the associated 90% confidence bands calculated using Newey-West standard errors.

B Derivations

B.1 Derivation of entrepreneurs' consumption

Define $\psi_t \equiv m_t \mathrm{E}_t \left[\frac{q_{t+1}\pi_{t+1}}{R_t^B}\right]$ so that Eq. (11) could be written as

$$b_t = \psi h_t^e \tag{40}$$

Then using Eq. (13) and Eq. (14) from the entrepreneurs maximization problem I get:

$$\frac{q_t - \psi_t}{c_t^e} = \beta^e \mathrm{E}_t \left[\frac{\alpha \frac{y_{t+1}}{x_{t+1}} \frac{1}{h_t^e} + q_{t+1} - R_t^B \frac{\psi_t}{\pi_{t+1}}}{c_{t+1}^e}\right] \tag{41}$$

Using Eq. (12) and Eq. (40) I can rewrite Eq. (16), the definition of real net worth as:

$$nw_t = \left(\frac{\alpha y_t}{x_t h^e_{t-1}} + q_t - \frac{R^B_{t-1}\psi_{t-1}}{\pi_t} \right) h^e_{t-1} \tag{42}$$

Recall that according to Eq. (15), every period entrepreneurs consume a constant fraction from their nw^e:

$$c^e_t = (1 - \beta^e) nw^e_t$$

Using Eq. (15) and Eq. (42) in Eq. (41) I get:

$$\begin{aligned} \frac{q_t - \psi_t}{c^e_t} &= \beta^e \mathrm{E}_t \left[\frac{nw^e_{t+1}/h^e_t}{(1-\beta^e) nw^e_{t+1}} \right] \\ &= \frac{\beta^e}{(1-\beta^e) h^e_t} \end{aligned} \tag{43}$$

Using Eq. (40) and Eq. (42) I can rewrite Eq. (10), the entrepreneurs budget constraint as:

$$\begin{aligned} c^e_t + q_t h^e_t &= \psi_t h^e_t + \frac{y_t}{x_t} - w_t l^d_t + q_t h^e_{t-1} - \frac{R^B_{t-1} b_{t-1}}{\pi_t} \\ &= \psi_t h^e_t + nw^e_t \end{aligned} \tag{44}$$

simplifying Eq. (43) to:

$$q_t h^e_t - \psi_t h^e_t - \beta^e q_t h^e_t + \beta^e \psi_t h^e_t - \beta^e c^e_t = 0 \tag{45}$$

and using Eq. (44) in Eq. (45) gives

$$nw^e_t - c^e_t - \beta^e nw^e_t = 0 \tag{46}$$

which verifies that Eq. (15) holds.

B.2 Derivation of banks' lending spread

I present the derivation of the optimal spread between the deposit rate and the loan rate, Eq. (30). The derivation builds heavily on the proof presented in the technical appendix of Andrés and Arce (2012).

I start by rewriting Eq. (29) as:

$$R_t^B(i) = R_t^D + \frac{1}{\Omega_t^k + \Omega_t^*} \tag{47}$$

where $\Omega_t^k \equiv -\frac{\partial b_t^k(i)}{\partial R_t^B(i)} \frac{1}{b_t^k(i)}$ and $\Omega_t^* \equiv -\frac{\partial b_t^*(i)}{\partial R_t^B(i)} \frac{1}{b_t^*(i)}$.

To find Ω_t^k, I first use the entrepreneurs budget constraint, Eq. (10), and the defenition of nw_t^e, Eq. (16), in Eq. (15) to get:

$$q_t h_t^e - b_t^k(i) = \beta^e nw_t^e \tag{48}$$

Using the entrepreneur borrowing constraint, Eq. (11), in Eq. (48), I can express the demand for loans of entrepreneur k from bank i at time t as:

$$b_t^k(i) = \frac{\beta^e nw_t^e}{q_t \left[\frac{R_t^B(i)}{m_t E_t(q_{t+1}\pi_{t+1})}\right] - 1} \tag{49}$$

I can then use Eq. (49) to get

$$\begin{aligned} \Omega_t^k &= -\frac{\partial b_t^k(i)}{\partial R_t^B(i)} \frac{1}{b_t^k(i)} \\ &= \frac{q_t \beta^e nw_t^e m_t E_t(q_{t+1}\pi_{t+1})}{\left[q_t R_t^B(i) - m_t E_t\left(q_{t+1}\pi_{t+1}\right)\right]^2} \frac{1}{b_t^k(i)} \end{aligned} \tag{50}$$

From Eq. (11) I can use $m_t E_t(q_{t+1}\pi_{t+1}) = b_t^k(i) R_t^B(i)/h_t^e$ and after some algebra, Eq. (50) simplifies to:

$$\Omega_t^k = \frac{1}{R_t^B(i) - \frac{m_t}{q_t} E_t\left(q_{t+1}\pi_{t+1}\right)} \tag{51}$$

The next step is to find Ω_t^*. First, recall that a mass one of identical entrepreneurs are distributed uniformly around a circumference where banks are also located symmetrically. At each period t, each entrepreneur chooses which banks to obtain funds from, based on the loan rate charged by the bank and the distance from the bank. The symmetric set-up of the model implies that all banks set the same loan rate R_t^B. I can identify an entrepreneur k, which is located exactly between bank i and $i+1$ using the following equality:

$$E_t\left[\beta^e \log c^{e,i}_{t+1}\right] - \kappa\delta^{k,i}_t = E_t\left[\beta^e log c^{e,i+1}_{t+1}\right] - \kappa\delta^{k,i+1}_t \qquad \forall t \tag{52}$$

This entrepreneur is indifferent between going to bank i or $i+1$ since they both offer the same rate and are located at an equal distance. Recall that in every period t, the entrepreneur consumes a constant fraction of her net worth, nw^e_t, which does not depend on the current banking choice as can be seen in Eq. 15. Thus, in Eq. (52) the optimal levels of consumption at time $t+1$ are the same when obtaining a loan at time t from bank i ($\log c^{e,i}_{t+1}$) or bank $i+1$ ($\log c^{e,i+1}_{t+1}$).

Since the banks are located symmetrically, I can express the distance between any two banks as $\frac{1}{n}$. Thus, the distance between the indifferent entrepreneur and bank $i+1$ can be expressed as $\delta^{k,i+1}_t = \frac{1}{n} - \delta^{k,i}_t$. Using this distance measure and Eq. (15) I can rewrite Eq. (52) as:

$$\frac{\beta^e}{1-\beta^e} E_t\left[\log nw^{e,i}_{t+1} - \log nw^{e,i+1}_{t+1}\right] = \kappa\left(2\delta^{k,i}_t - \frac{1}{n}\right) \tag{53}$$

solving for $\delta^{k,i}_t$:

$$\delta^{k,i}_t = \frac{1}{2n} + \frac{1}{2\kappa}\frac{\beta^e}{1-\beta^e} E_t\left[\log nw^{e,i}_{t+1} - \log nw^{e,i+1}_{t+1}\right] \tag{54}$$

Eq. (54) could be interpenetrated as the area where any located entreprenures will choose to go to bank i. This could be derived in exactly the same way for the area between bank i and bank $i-1$. Thus, bank's i market share can be expressed as the total area on the circumference where entrepreneurs choose to go to bank i:

$$b^*_t(i) = \frac{1}{n} + \frac{1}{2\kappa}\frac{\beta^e}{1-\beta^e} E_t\left[2\log nw^{e,i}_{t+1} - \log nw^{e,i+1}_{t+1} - \log nw^{e,i-1}_{t+1}\right] \tag{55}$$

Using Eq. (15), the definition of nw^e_t, Eq. (10) the entrepreneurs' budget constraint, and Eq. (11)-the collateral constrain, I can express the entrepreneur net worth at time $t+1$ when taking a loan from bank i at time t as:

$$nw^{e,i}_{t+1} = \beta^e \frac{\alpha\frac{y_{t+1}}{x_{t+1}h_{t+1}} + q_{t+1} - m_t\frac{E_t(q_{t+1}\pi_{t+1})}{\pi_{t+1}}}{q_t - \frac{E_t(q_{t+1}\pi_{t+1})}{R^B_t(i)}} nw^e_t \tag{56}$$

Using Eq. (56) and Eq. (55) I can find:

$$\Omega_t^* = \frac{n\beta^e}{\kappa(1-\beta^e)} \left[\frac{m_t E_t\left(\frac{q_{t+1}}{q_t}\pi_{t+1}\right)}{\left(R_t^B - m_t E_t\left(\frac{q_{t+1}}{q_t}\pi_{t+1}\right)\right) R_t^B} \right] \tag{57}$$

where I also use the fact that in equilibrium $\frac{1}{b_t^*(i)} = n\ \forall i$, since the market share of every bank is simply $\frac{1}{n}$. Also, symmetry across banks allows me to drop the subscript i from the loan rate.

The final step is using Eq. (51) and Eq. (57) in Eq. (47), which gives the equation for the optimal interest rate margin, Eq. (30).

C Steady State and Log-Linearization

C.1 Equilibrium and other definitions

The steady state of the model is defined by the following equations (no time subscripts denote steady state values).

$$\begin{aligned}
&\pi = 1 \\
&R^D = \frac{1}{\beta} \\
&x = \frac{\varepsilon}{\varepsilon - 1} \\
&\frac{qh^e}{y} = \frac{\beta^e \alpha}{1-\beta^e - m(1/R^B - \beta^e)} \\
&\frac{qh}{c} = \frac{j}{1-\beta} \\
&\frac{div}{y} = \left(R^B - \frac{1}{\beta}\right) m \frac{qh^e}{y} \\
&\frac{c^e}{y} = (1-\beta^e)\left[\frac{\alpha}{x} + (1-m)\frac{qh^e}{y}\right] \\
&\frac{c}{y} = \frac{x-\alpha}{x} + \left(R^D - 1\right) m \frac{1}{R^B}\frac{qh^e}{y} + \frac{div}{y} \\
&R^B - R^D = \frac{R^D - m}{\eta m - R^D} R^D \\
&\eta = 1 + \frac{n}{\kappa}\frac{\beta^e}{1-\beta^e} \\
&\frac{h}{h^e} = \frac{j\left[1-\beta^e - m\left(\frac{1}{R^B} - \beta^e\right)\right]}{(1-\beta)\beta^e\alpha}\frac{c}{y}
\end{aligned}$$

C.2 Complete log-linearized model

The model can be reduced to the following system of linearized equations. Variables with a hat denote deviations from the steady state and variables with no time subscripts indicate steady-state values.

Optimal decisions of households and entrepreneurs:

$$\hat{c}_t = E_t\left(\hat{c}_{t+1} + \hat{\pi}_{t+1}\right) - \hat{R}_t^D$$

$$\hat{q}_t = \beta E_t\left(\hat{q}_{t+1} - \hat{c}_{t+1}\right) + (1-\beta)\left(\hat{j}_t - \hat{h}_t\right) + \hat{c}_t$$

$$\hat{c}_t^e = \beta^e R^B E_t\left(\hat{c}_{t+1}^e - \hat{R}_t^B + \hat{\pi}_{t+1}\right) - \left(1 - \beta^e R^B\right)\hat{\lambda}_t^e$$

$$\hat{b}_t = \hat{m}_t + \hat{h}_t^e + E_t\left(\hat{q}_{t+1} + \hat{\pi}_{t+1}\right) - \hat{R}_t^B$$

$$\hat{q}_t = \beta^e\left[\frac{\alpha y}{x h^e q}\left(\hat{y}_{t+1} - \hat{x}_{t+1} - \hat{h}_t^e - \hat{c}_{t+1}^e\right)\right] + \left(\frac{1}{R^B} - \beta^e\right) m\left[\hat{\lambda}_t^e + \hat{m}_t + E_t\left(\hat{q}_{t+1} + \hat{\pi}_{t+1}\right) - \hat{R}_t^B\right] + \hat{c}_t^e$$

$$\hat{c}_t^e = (1-\beta^e)\frac{y}{c^e}\left[\frac{\alpha}{x}\left(\hat{y}_t - \hat{x}_t\right) + \frac{q h^e}{y}\left(\hat{q}_t + \hat{h}_{t-1}^e\right) - m\frac{q h^e}{y}\left(\hat{R}_{t-1}^B + \hat{b}_{t-1} - \hat{\pi}_t\right)\right]$$

Banks' and final good firms' profit maximization:

$$\hat{R}_t^B = \hat{R}_t^D + \frac{\hat{R}_t^D - \hat{m}_t - \hat{\pi}_{t+1} - \hat{q}_{t+1} + \hat{q}_t}{\eta m\left(1 + \hat{m}_t + \hat{\pi}_{t+1} + \hat{q}_{t+1} - \hat{q}_t\right) - R^D\left(1 + \hat{R}_t^D\right)} R^D$$

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} - \frac{(1-\theta)(1-\beta\theta)}{\theta}\hat{x}_t$$

$$\hat{x}_t = \hat{y}_t - \hat{c}_t - \frac{1+\varphi}{1-\alpha}\left(\hat{y}_t - \hat{A}_t - \alpha\hat{h}_{t-1}^e\right)$$

Policy rules and equilibrium conditions:

$$\hat{m}_t = \phi_m \hat{b}$$

$$\hat{R}_t^D = (1-\phi_R)\left(\phi_\pi\hat{\pi}_t + \phi_Y\hat{Y}_t + \phi_b\hat{b}_t\right) + \phi_R\hat{R}_t^D + u_{R,t}$$

$$\hat{y}_t = \frac{c}{y}\hat{c}_t + \frac{c^e}{y}\hat{c}_t^e$$

$$\hat{h}_t^e = -\frac{h}{h^e}\hat{h}_t$$

Shock processes

$$\hat{j}_t = \rho_j\hat{j}_{t-1} + u_{j,t}$$

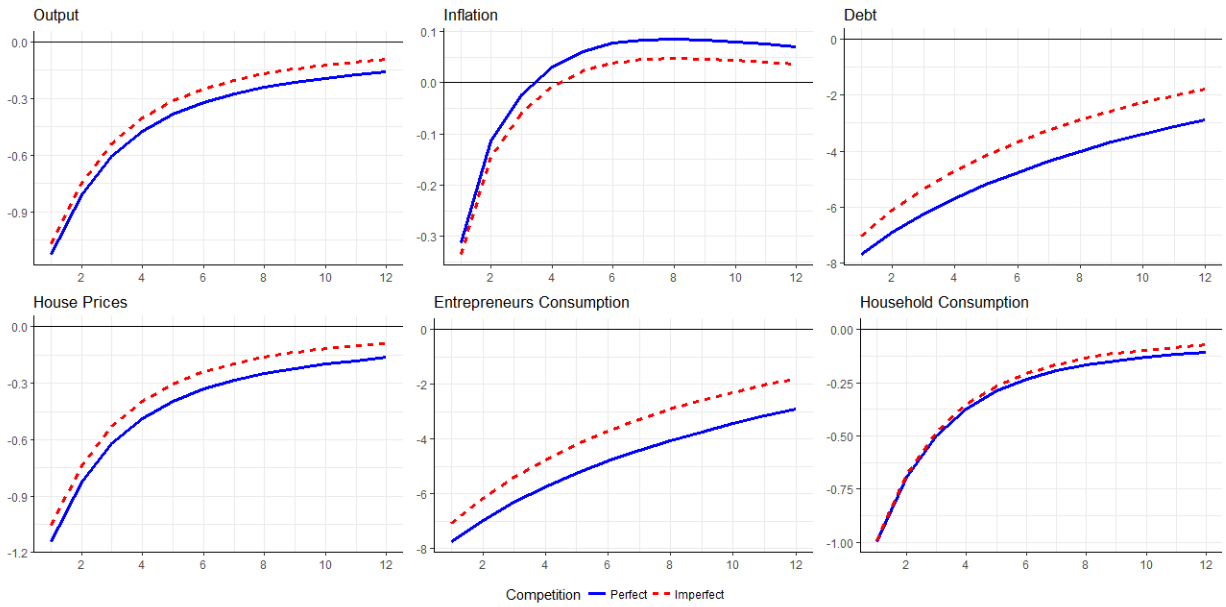
$$\hat{A}_t = \rho_A\hat{A}_{t-1} + u_{A,t}$$

D Figures and Tables

Table 2: Parameter values

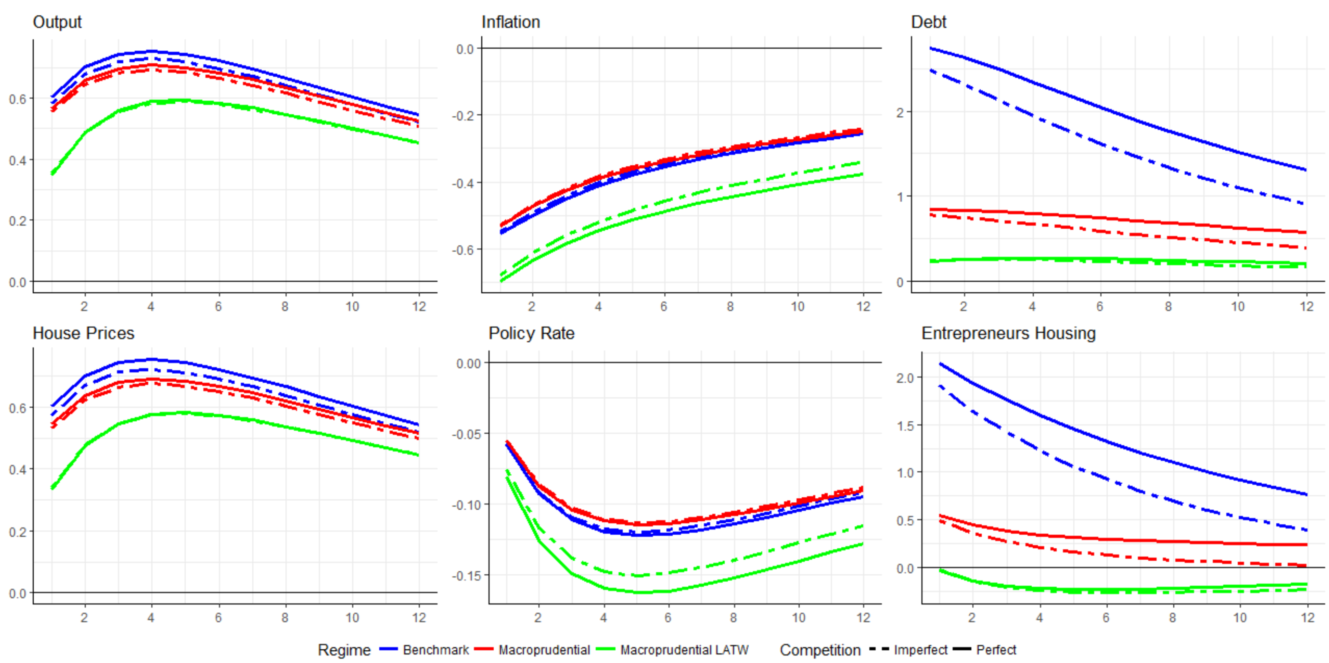
Parameter	Description	Value
β	Household discount factor	0.9925
β^e	Entrepreneur discount factor	0.97
j	Weight of housing in the households' utility	0.12
φ	Inverse of labor supply elasticity	0.51
α	Housing share in production	0.05
θ	Calvo parameter	0.83
ε	elasticity of substitution	7.76
m	Steady-state LTV ratio	0.85
n/κ	Bank competition parameter	0.7845
Shock processes:		
ρ_A	Autocorrelation of technology shock	0.95
ρ_j	Autocorrelation of house demand shock	0.96
σ_j	Standard deviation house demand shock (in %)	4.16
σ_A	Standard deviation technology shock (in %)	1
σ_R	Standard deviation monetary shock (in %)	0.34
Policy parameters (Baseline parametrization):		
ϕ_R	Monetary policy Smoothing parameter	0.8
ϕ_π	Monetary policy coefficient on inflation	2
ϕ_Y	Monetary policy coefficient on output	0.125
ϕ_b	Monetary policy coefficient on debt	0.3
ϕ_m	Macroprudential policy coefficient on debt	0.3

Figure 3: Contractionary Monetary Shock - Baseline Model



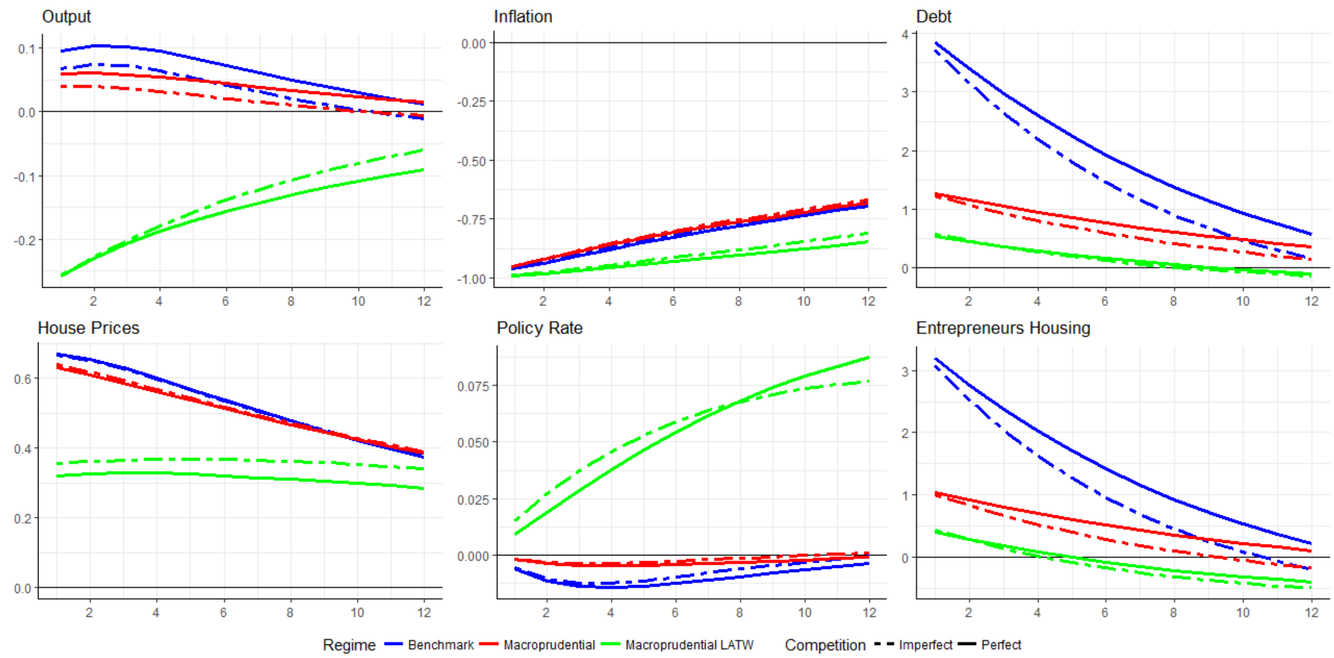
Notes: Response of key variables to a contractionary monetary policy shock. The figure compares between an economy with perfect and imperfect competitive banking sector. Horizontal axis measures quarters after the shock. Vertical axis are deviation from steady state values (in %). Inflation is in annualized terms.

Figure 4: Comparing Regimes - Technology Shock



Notes: Response of key variables to a positive technological shock. The figure compares between three policy regimes: standard Taylor rule (Benchmark), standard Taylor rule with countercyclical LTV rule (Macroprudential), and LATW monetary rule with countercyclical LTV rule (Macroprudential_LATW). Horizontal axis measures quarters after the shock. Vertical axis are deviation from steady state values (in %). Inflation is in annualized terms.

Figure 5: Comparing Regimes - Housing Demand Shock



Notes: Response of key variables to a positive housing demand shock. The figure compares between three policy regimes: standard Taylor rule (Benchmark), standard Taylor rule with countercyclical LTV rule (Macroprudential), and LATW monetary rule with countercyclical LTV rule (Macroprudential_LATW). Horizontal axis measures quarters after the shock. Vertical axis are deviation from steady state values (in %). Inflation is in annualized terms.

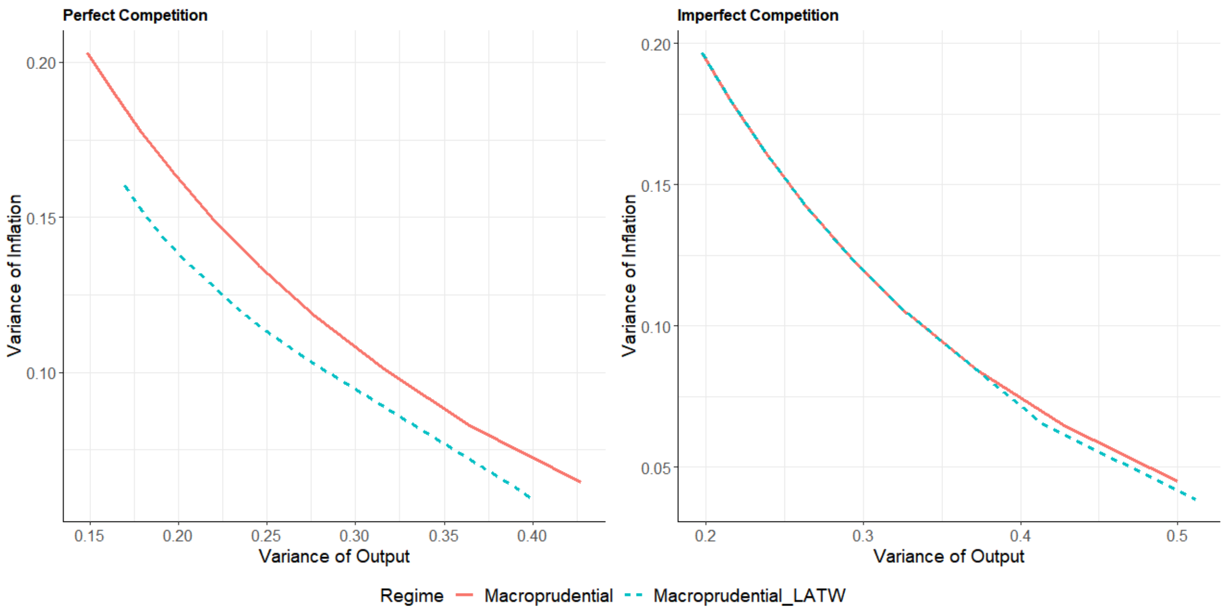
Table 3: Optimal policy rule coefficient

	Perfect Competition					Imperfect Competition				
	ϕ_π	ϕ_Y	ϕ_m	ϕ_b	Loss*	ϕ_π	ϕ_Y	ϕ_m	ϕ_b	Loss*
Panel A - technology shock										
$\zeta_y = 0.25 \quad \zeta_b = 0.25$										
Benchmark	1.20	0.5			0.18	1.20	0.5			0.18
Macroprudential	1.10	0.4	2.00		0.17	1.10	0.3	2.00		0.17
Macroprudential LATW	1.10	0.1	0.00	2.00	0.16	1.10	0.1	2.00	2.00	0.17
$\zeta_y = 0.5 \quad \zeta_b = 0.25$										
Benchmark	1.20	0.5			0.28	1.20	0.5			0.28
Macroprudential	1.10	0.7	2.00		0.26	1.10	0.6	2.00		0.27
Macroprudential LATW	1.10	1.3	1.70	2.00	0.24	1.10	0.6	2.00	0.00	0.42
$\zeta_y = 1 \quad \zeta_b = 0.25$										
Benchmark	2.90	1.7			0.46	3.00	1.8			0.46
Macroprudential	1.10	1.2	2.00		0.37	1.10	1.1	2.00		0.40
Macroprudential LATW	1.10	2	2.00	2.00	0.34	1.10	1.1	2.00	0.00	0.40
Panel B - housing demand shock										
$\zeta_y = 0.25 \quad \zeta_b = 0.25$										
Benchmark	1.50	2			1.29	1.80	2			1.07
Macroprudential	3.00	1.7	2.00		0.01	3.00	1.3	2.00		0.01
Macroprudential LATW	1.30	0	2.00	0.20	0.01	1.20	0	2.00	0.20	0.01
$\zeta_y = 0.5 \quad \zeta_b = 0.25$										
Benchmark	1.50	2			1.29	1.80	2			1.07
Macroprudential	2.90	1.8	2.00		0.01	3.00	1.5	2.00		0.01
Macroprudential LATW	1.50	0	2.00	0.20	0.01	1.70	0	2.00	0.20	0.01
$\zeta_y = 1 \quad \zeta_b = 0.25$										
Benchmark	1.50	2			1.29	1.70	2			1.07
Macroprudential	2.80	2	2.00		0.01	3.00	1.9	2.00		0.01
Macroprudential LATW	1.10	0.2	2.00	0.10	0.01	1.10	0.2	2.00	0.10	0.01

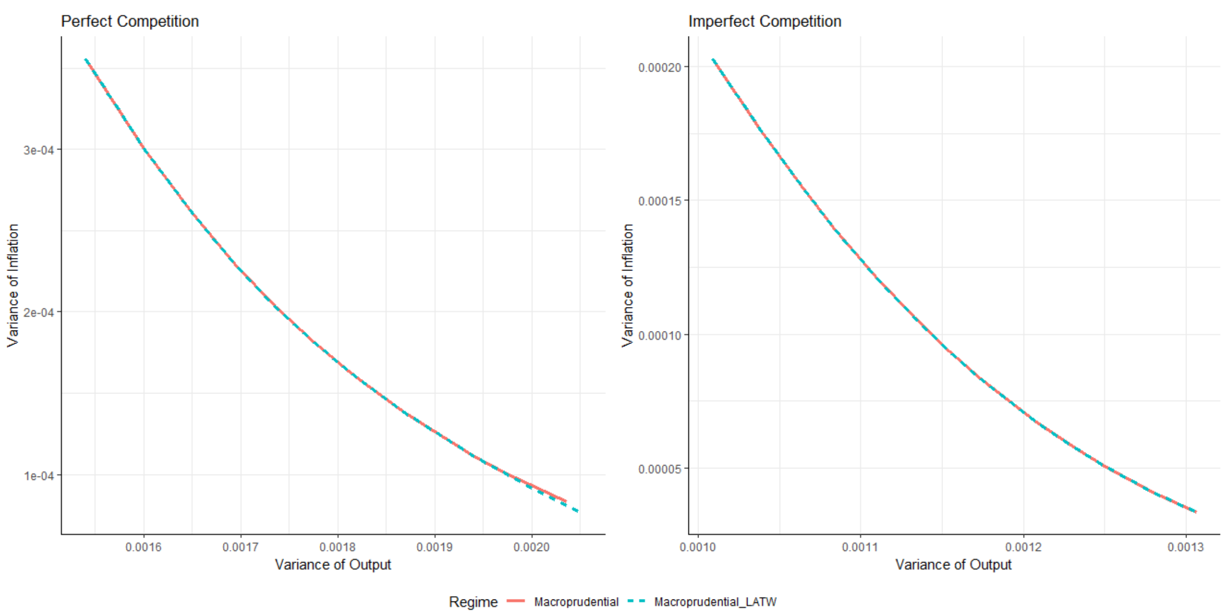
Notes: Table reports optimal policy coefficients under alternative policy rules and banks' competition. The table also reports policymakers loss function value $Loss = Var(\pi) + \zeta_y Var(Y) + \zeta_b Var(b)$.

* The value of the Loss is multiplied by 1000.

Figure 6: Efficiency policy frontier



(a) Technology shock



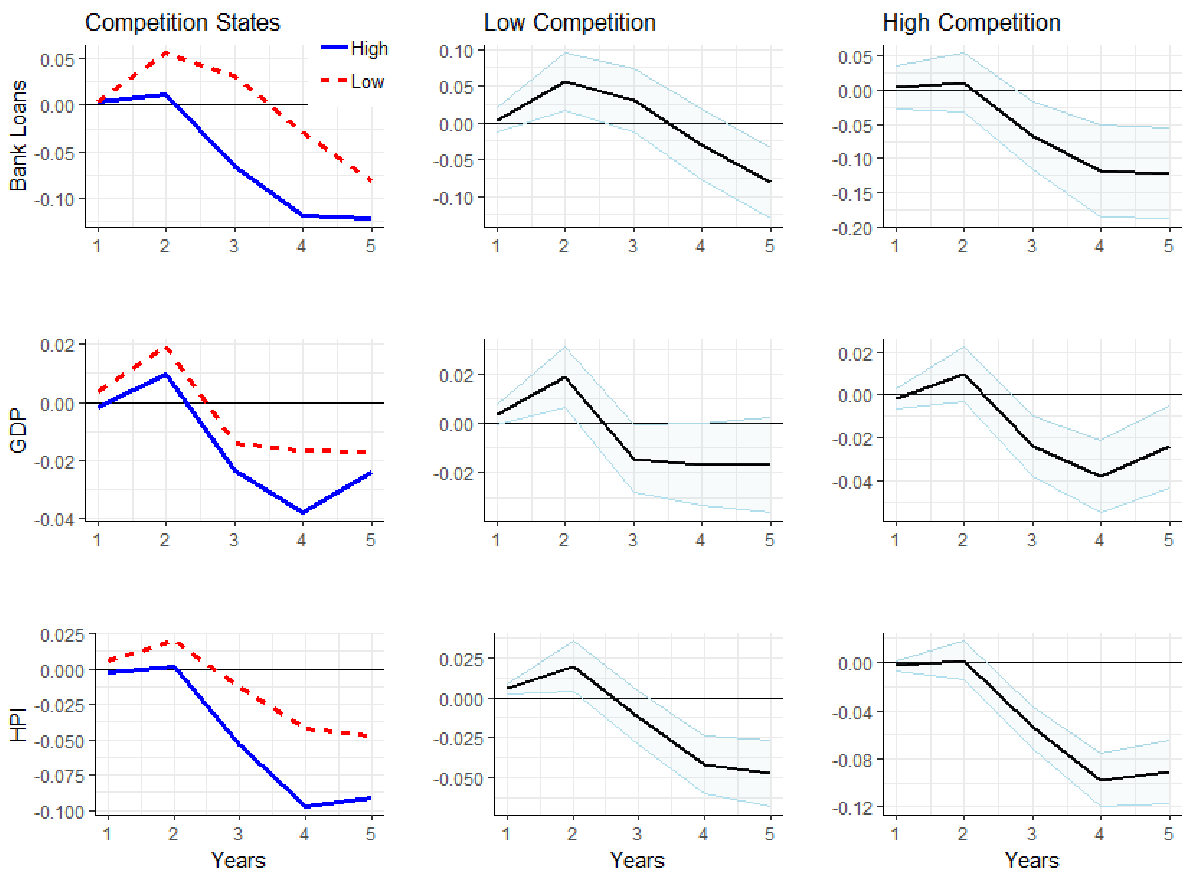
(b) Housing demand shock

Note: The figure reports the efficiency policy frontier of a macroprudential and macroprudential + LATW policy regime. Panel A reports the variance of output and inflation for each policy regime after a technology shock and Panel B for a housing demand shock.

E Online Appendix (not for publication)

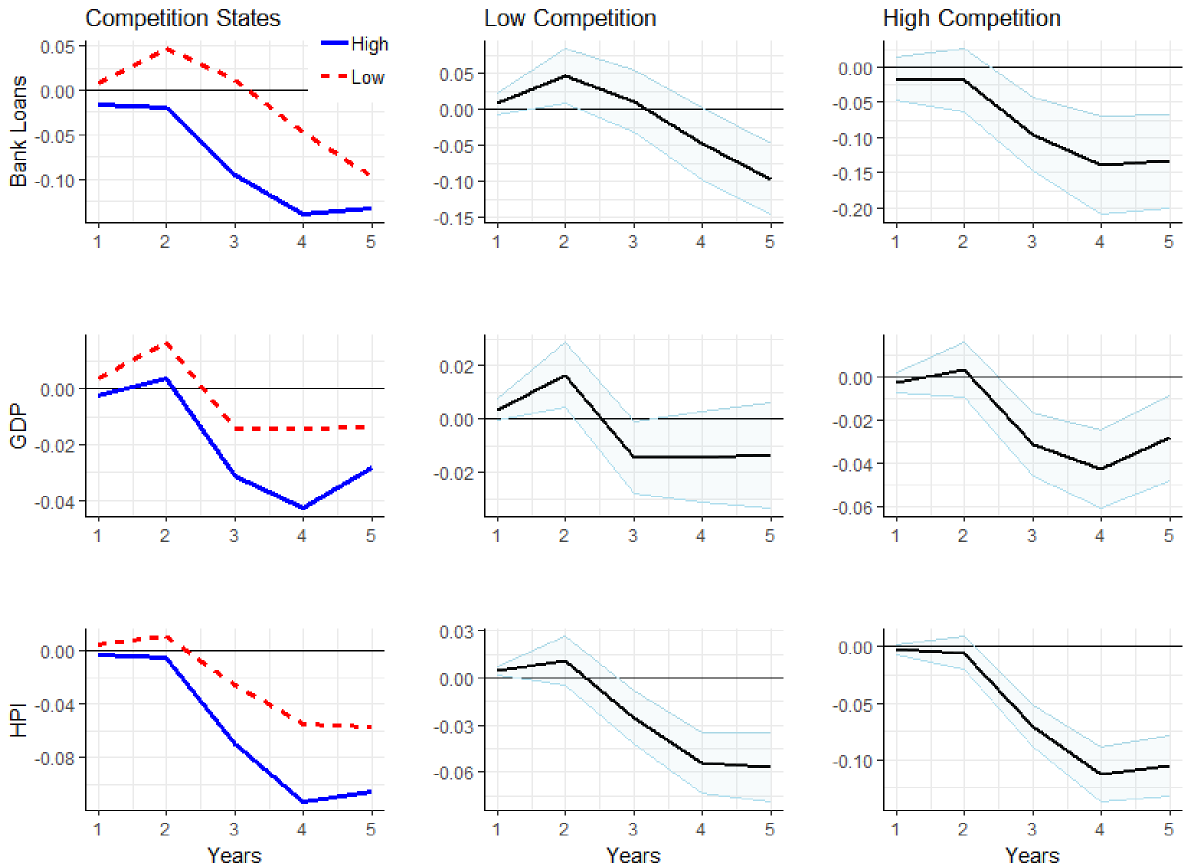
E.1 Alternative empirical specifications

Figure 7: Robustness; alternative specification - lagged dependent variable and monetary shock



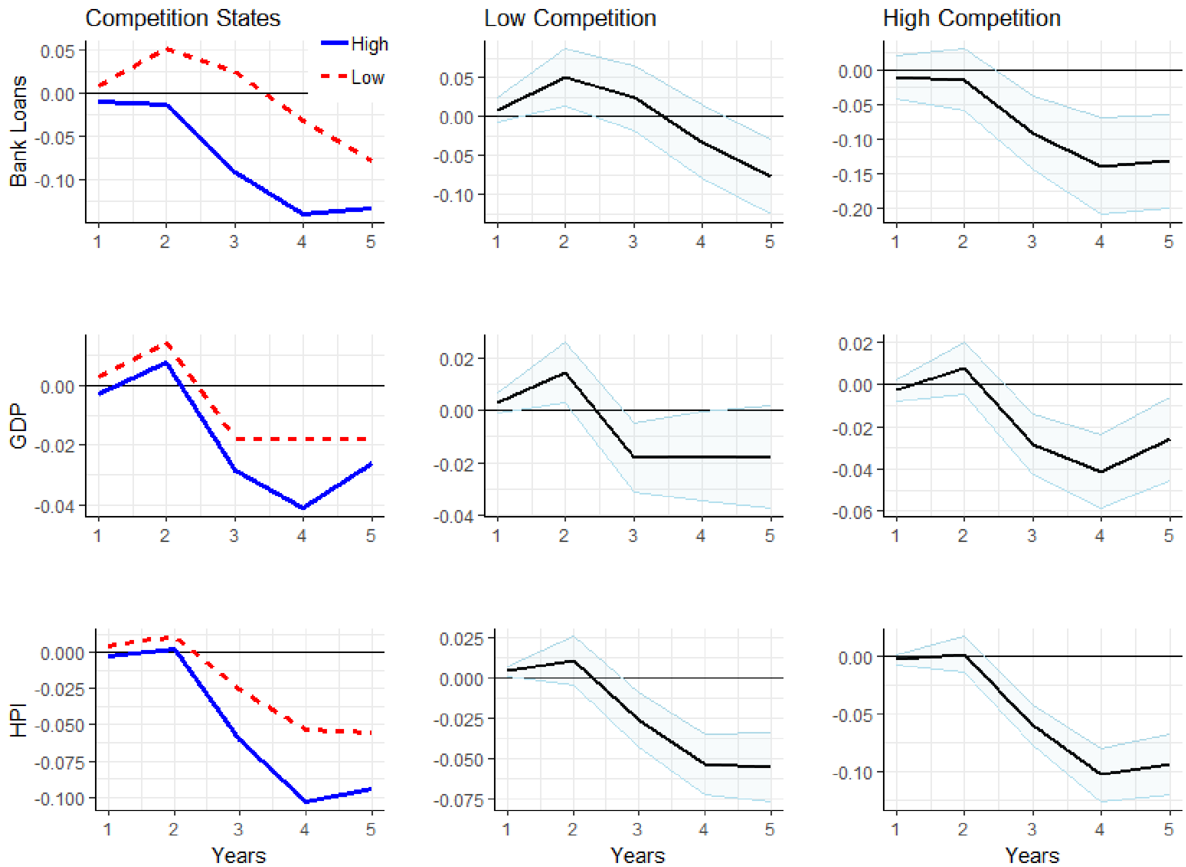
Note: Impulse response to an increase in the effective federal funds rate of 100 basis points. The first column shows the responses in states with high (blue-solid line) and low (red-dashed line) bank competition. 2nd and 3rd columns show the responses with the associated 90% confidence bands calculated using Newey-West standard errors. Estimates based on Eq. (1) with one lag of each dependent variable and the monetary shock.

Figure 8: Robustness; alternative specification - controlling for bank concentration



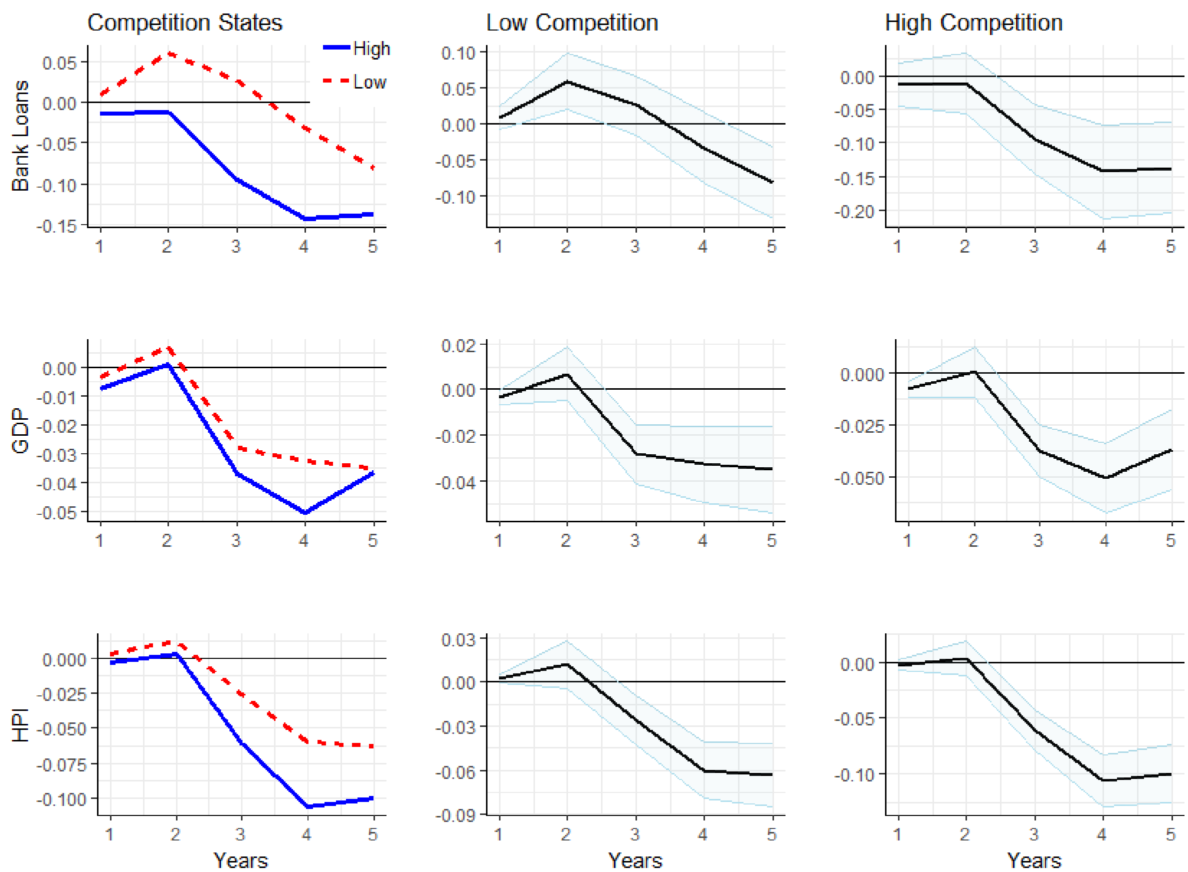
Note: Impulse response to an increase in the effective federal funds rate of 100 basis points. The first column shows the responses in states with high (blue-solid line) and low (red-dashed line) bank competition. 2nd and 3rd columns show the responses with the associated 90% confidence bands calculated using Newey-West standard errors. Estimates based on Eq. (1) with log of the deposit based Herfindahl Hirshman index as additional state-level control.

Figure 9: Robustness; alternative specification - controlling for state-level inflation



Note: Impulse response to an increase in the effective federal funds rate of 100 basis points. The first column shows the responses in states with high (blue-solid line) and low (red-dashed line) bank competition. 2nd and 3rd columns show the responses with the associated 90% confidence bands calculated using Newey-West standard errors. Estimates based on Eq. (1) with log change of the state-level inflation as additional control.

Figure 10: Robustness; alternative specification - controlling for convergence effects



Note: Impulse response to an increase in the effective federal funds rate of 100 basis points. The first column shows the responses in states with high (blue-solid line) and low (red-dashed line) bank competition. 2nd and 3rd columns show the responses with the associated 90% confidence bands calculated using Newey-West standard errors. Estimates based on Eq. (1) with log of the state-level real GDP as additional control.

E.2 Alternative weight on debt in the Loss function

This subsection reports the results presented in Table 2 when using alternative values for ζ_b.

Table 4: Optimal policy rule coefficient

	Perfect Competition					Imperfect Competition				
	ϕ_π	ϕ_Y	ϕ_m	ϕ_b	Loss*	ϕ_π	ϕ_Y	ϕ_m	ϕ_b	Loss*
Panel A - technology shock										
$\zeta_y = 0.25 \quad \zeta_b = 0.1$										
Benchmark	1.20	0.5			0.17	1.10	0.4			0.18
Macroprudential	1.10	0.4	2.00		0.17	1.10	0.3	2.00		0.17
Macroprudential LATW	1.10	0	0.00	2.00	0.16	1.10	0	1.20	2.00	0.17
$\zeta_y = 0.5 \quad \zeta_b = 0.1$										
Benchmark	1.20	0.5			0.27	1.20	0.5			0.28
Macroprudential	1.10	0.7	2.00		0.26	1.10	0.6	1.40		0.27
Macroprudential LATW	1.10	1.5	1.30	2.00	0.24	1.10	0.6	1.40	0.00	0.42
$\zeta_y = 1 \quad \zeta_b = 0.1$										
Benchmark	2.70	1.7			0.45	3.00	2			0.45
Macroprudential	1.10	1.3	2.00		0.36	1.10	1.1	2.00		0.40
Macroprudential LATW	1.10	2	2.00	2.00	0.33	1.10	1.1	2.00	0.00	0.40
Panel B - housing demand shock										
$\zeta_y = 0.25 \quad \zeta_b = 0.1$										
Benchmark	1.60	2			0.52	1.80	2			0.43
Macroprudential	2.60	1	2.00		0.00	3.00	0.9	2.00		0.00
Macroprudential LATW	1.10	0	2.00	0.10	0.00	1.10	0	2.00	0.10	0.00
$\zeta_y = 0.5 \quad \zeta_b = 0.1$										
Benchmark	1.50	2			0.52	1.80	2			0.43
Macroprudential	2.40	1.1	2.00		0.01	3.00	1.1	2.00		0.00
Macroprudential LATW	1.10	0	2.00	0.10	0.00	1.40	0.1	2.00	0.10	0.01
$\zeta_y = 1 \quad \zeta_b = 0.1$										
Benchmark	1.50	2			0.52	1.80	2			0.43
Macroprudential	2.00	1.2	2.00		0.01	3.00	1.6	2.00		0.00
Macroprudential LATW	1.20	0.2	2.00	0.10	0.01	3.00	1.1	2.00	0.10	0.00

Notes: Table reports optimal policy coefficients under alternative policy rules and banks' competition. The table also reports policymakers loss function value $Loss = Var(\pi) + \zeta_y Var(Y) + \zeta_b Var(b)$.

* The value of the Loss is multiplied by 1000.

Table 5: Optimal policy rule coefficient

	Perfect Competition					Imperfect Competition				
	ϕ_π	ϕ_Y	ϕ_m	ϕ_b	Loss*	ϕ_π	ϕ_Y	ϕ_m	ϕ_b	Loss*
Panel A - technology shock										
$\zeta_y = 0.25 \quad \zeta_b = 0.5$										
Benchmark	1.20	0.5			0.18	1.20	0.5			0.18
Macroprudential	1.10	0.4	2.00		0.17	1.10	0.4	2.00		0.17
Macroprudential LATW	1.10	0.2	0.00	2.00	0.16	1.10	0.1	2.00	2.00	0.17
$\zeta_y = 0.5 \quad \zeta_b = 0.5$										
Benchmark	1.20	0.5			0.28	1.20	0.5			0.28
Macroprudential	1.10	0.6	2.00		0.26	1.10	0.6	2.00		0.27
Macroprudential LATW	1.10	1.1	2.00	2.00	0.25	1.10	0.6	2.00	0.00	0.42
$\zeta_y = 1 \quad \zeta_b = 0.5$										
Benchmark	2.70	1.5			0.47	2.80	1.6			0.47
Macroprudential	1.10	1.1	2.00		0.38	1.10	1	2.00		0.41
Macroprudential LATW	1.10	2	2.00	2.00	0.35	1.10	1	2.00	0.00	0.41
Panel B - housing demand shock										
$\zeta_y = 0.25 \quad \zeta_b = 0.5$										
Benchmark	1.50	2			2.58	1.70	2			2.14
Macroprudential	2.70	2	2.00		0.02	3.00	1.8	2.00		0.02
Macroprudential LATW	1.50	0	2.00	0.30	0.02	1.70	0	2.00	0.40	0.01
$\zeta_y = 0.5 \quad \zeta_b = 0.5$										
Benchmark	1.50	2			2.58	1.70	2			2.14
Macroprudential	2.60	2	2.00		0.02	3.00	1.9	2.00		0.02
Macroprudential LATW	1.10	0	2.00	0.20	0.02	1.70	0	2.00	0.30	0.02
$\zeta_y = 1 \quad \zeta_b = 0.5$										
Benchmark	1.50	2			2.58	1.70	2			2.15
Macroprudential	2.30	2	2.00		0.02	3.00	2	2.00		0.02
Macroprudential LATW	1.30	0	2.00	0.20	0.02	1.50	0	2.00	0.20	0.01

Notes: Table reports optimal policy coefficients under alternative policy rules and banks' competition. The table also reports policymakers loss function value $Loss = Var(\pi) + \zeta_y Var(Y) + \zeta_b Var(b)$.

* The value of the Loss is multiplied by 1000.

Table 6: Optimal policy rule coefficient

	Perfect Competition					Imperfect Competition				
	ϕ_π	ϕ_Y	ϕ_m	ϕ_b	Loss*	ϕ_π	ϕ_Y	ϕ_m	ϕ_b	Loss*
Panel A - technology shock										
$\zeta_y = 0.25 \quad \zeta_b = 1$										
Benchmark	1.40	0.6			0.19	1.40	0.6			0.19
Macroprudential	1.10	0.4	2.00		0.17	1.10	0.4	2.00		0.17
Macroprudential LATW	1.10	0.3	0.00	2.00	0.17	1.10	0.2	2.00	2.00	0.17
$\zeta_y = 0.5 \quad \zeta_b = 1$										
Benchmark	1.40	0.6			0.28	1.40	0.6			0.28
Macroprudential	1.10	0.6	2.00		0.27	1.10	0.5	2.00		0.27
Macroprudential LATW	1.10	0.9	2.00	2.00	0.25	1.10	0.5	2.00	0.00	0.45
$\zeta_y = 0.1 \quad \zeta_b = 1$										
Benchmark	2.60	1.4			0.48	2.60	1.4			0.47
Macroprudential	1.10	0.9	2.00		0.40	1.10	0.9	2.00		0.41
Macroprudential LATW	1.10	1.8	2.00	2.00	0.37	1.10	0.9	2.00	0.00	0.41
Panel B - housing demand shock										
$\zeta_y = 0.25 \quad \zeta_b = 1$										
Benchmark	1.50	2			5.15	1.70	2			4.29
Macroprudential	2.20	2	2.00		0.05	3.00	2	2.00		0.03
Macroprudential LATW	1.10	0	2.00	0.30	0.04	2.10	0	2.00	0.70	0.02
$\zeta_y = 0.5 \quad \zeta_b = 1$										
Benchmark	1.50	2			5.15	1.70	2			4.29
Macroprudential	2.10	2	2.00		0.05	3.00	2	2.00		0.03
Macroprudential LATW	1.20	0	2.00	0.30	0.04	1.40	0	2.00	0.40	0.04
$\zeta_y = 1 \quad \zeta_b = 1$										
Benchmark	1.50	2			5.16	1.70	2			4.29
Macroprudential	2.00	2	2.00		0.05	2.90	2	2.00		0.03
Macroprudential LATW	1.50	0	2.00	0.30	0.04	1.50	0	2.00	0.30	0.03

Notes: Table reports optimal policy coefficients under alternative policy rules and banks' competition. The table also reports policymakers loss function value $Loss = Var(\pi) + \zeta_y Var(Y) + \zeta_b Var(b)$.

* The value of the Loss is multiplied by 1000.