Macroprudential and Monetary Policies with Regional Heterogeneous Banking Sector: From Empirical Evidence to Aggregate Implications

Nimrod Segev *

February 13, 2018

Preliminary and Incomplete

Abstract

This paper studies the effect of regional heterogeneous financial condition on the optimal use of monetary and macroprudential policies. Using bank-level data, I show that regional differences in financial conditions, specifically banks’ market power, shape the effectiveness of monetary policy transmission. Using the U.S. branching deregulation between 1994 and 2005 as an exogenous change in banks competition, I provide evidence for a negative relationship between banks’ market power and monetary policy effectiveness. I then develop a New Keynesian DSGE model with collateral constraints and an imperfect competitive banking sector and use it to explore the aggregate implications for monetary and macroprudential policies arising from the regional evidence. Overall, preliminary results suggest that policymakers should track the regional levels of banks’ competition.

Keywords: Monetary policy, Macroprudential policy, Financial stability, Banking competition, Lending spreads, Collateral constraints.

JEL Classification code: E32, E44, E52, E58, G21, G28

*Fordham University, Department of Economics, E-503 Dealy Hall, 441 East Fordham Road, Bronx, NY, 10458, nsegev@fordham.edu.
1 Introduction

The recent financial crisis has lead to a re-examination of how policymakers should deal with unsustainable credit booms. Figure 1 shows that household leverage increased by more than 50 percent while debt per capita more than doubled in the U.S. between 1999 to 2006. Indeed, recent research shows 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). These evidence have lead 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. The heart of the debt is over the role that monetary policy should take in mitigating financial vulnerability. On one hand, some argue that the limitations of macroprudential tools and the lack of conclusive empirical evidence regarding their effectiveness suggests that monetary policy should also 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 over the optimal mix of monetary policy and macroprudential tools by investigating the extent to which heterogeneous credit supply factors, such as financial deregulation and banks’ competition, shape the effectiveness and optimal implementation of the two tools.

The paper is motivated by recent studies which suggest that local heterogeneous credit supply factors, such as financial deregulation and the loosening of credit standards, contributed to the expansion of credit before the crisis (Mian and Sufi 2009; Favara and Imbs 2015). A striking feature of the recent crisis was the significant variations in the magnitude of the boom-bust cycle across states in the U.S. The regional variation is documented by Figures 2 and 3, which plot the time series of debt-to-income and debt per capita by state in the years leading to the crisis. The figures show the significant differences in the size of the boom-bust cycle across states. Additionally, the variation does not seem to follow any regional specific pattern. Figure 4 presents the percent increase in household leverage and debt between 1999 to 2006 on a U.S. "heat map". The map demonstrates that the differences across states are not limited to one
geographical region. In fact, in many parts of the U.S., neighboring states had very different levels of credit expansion. These stylized facts suggest that local financial conditions mattered in the recent crisis and the variation across states. Therefore, better empirical understanding of the forces that may have shaped these differences is warranted. Additionally, to establish some policy implications, a micro-founded general equilibrium model is needed to understand what these regional discrepancies imply for the use of monetary and macroprudential policies.

This paper is also motivated by a parallel inconclusive debate over how deregulation and bank competition contributes to financial instability. Following the crisis, policymakers have expressed a general belief that a trade-off exists between competition in the banking sector and financial stability. Vives (2016) argues that policymakers can mitigate the competition-stability trade-off by coordinating competition policy with the new suggested prudential policies. However, to the best of my knowledge, there is very little research about 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 detailed bank-level data to explore the role that market power and financial deregulation jointly play in the transmission of monetary policy. My investigation is made possible by using the differences in regulatory barriers to interstate branching in the U.S. between 1994 to 2005 as a "quasi-natural experiment" to test how different levels of regulation and banking competition interact with monetary policy. Preliminary empirical findings show that banks in deregulated states are more affected by changes in monetary policy. These results suggest that different levels of banks competition and regulation can significantly shape the transmission of monetary policy, and should be taken into consideration when conducting monetary policy.

Second, I develop a New Keynesian DSGE model with financial frictions in the form of imperfect competitive banking sector and collateral constraint. The model captures some of

1For 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 promotion competition is one of the regulation authority objectives, it is secondary to the primary objective which is maintaining stability (Bank of England 2015).
the key aspects of the data developed in the empirical part. Most importantly, in the model, the level of household debt and the reaction to monetary policy shocks depends on the level of banks competition. I use the model to (i) quantify how imperfect competition in the banking sector shapes the aggregate response of the economy to different shocks, and (ii) investigate what levels of banking competition imply for the implementation and coordination of monetary and macroprudential policies. The preliminary simulation results suggest that an optimal mix of macroprudential regulation and monetary mix could benefit from taking into account the intensity of banks’ competition. Additional, the result demonstrates that given the interaction between monetary policy, regulation and banks’ market power, there may be an optimal degree of banks competition.

This paper makes several contributions to the existing literature. On the empirical front, this paper is the first to use the U.S. branching deregulation as a "quasi-natural experiment" to investigate how local financial conditions shape the effectiveness of monetary policy. In the context of macro models, this research is the first to consider regional heterogeneous credit supply factors (banks’ competition) when investigating the optimal use of macroprudential and monetary policies.

From a policy point of view, this research is important since it investigates the extent to which policymakers should track levels of bank competition and local financial conditions when using monetary and macroprudential policies to boost macroeconomic and financial stability. This line of research is especially relevant to the current rise in bank concentration in the U.S. and worldwide. According to the estimates shown in this paper, the recent surge in bank consolidation may reduce the effectiveness of monetary policy transmission and potentially change the optimal policy reaction to economic and financial conditions. Finally, the paper contributes to the literature that tries to explain the causes of the Great Recession.2 While identifying the exact forces which led to the Great Recession is beyond the scope of this research, this paper suggests that local credit supply conditions such as deregulation and increase in banks competition may have amplified the size of the boom-bust cycle in some regions in the U.S.

The paper proceeds as follows. Section 2 reviews related literature. Section 3 presents the empirical investigation. Sections 4 and 5 present the basic model, the preliminary simulation results, and discusses possible extensions. Section 6 concludes.

2 Related Literature

In this section, I will review the connection of this study to the existing literature.

2.1 Empirical

Empirically, this paper is related to several strands of the literature.

First, this paper is related to a very large body of empirical research which studies how credit market imperfections shape the transmission of monetary policy through financial intermediaries.\(^3\) Within this broad spectrum of research, this paper is most closely related to the literature which studies how banking market power influences the transmission of monetary policy. The literature provides contradicting evidence regarding the effect of bank competition on the effectiveness of monetary policy. For example, Adams and Amel (2011) use aggregate U.S. data to show that there is a negative relationship between banking sector concentration and monetary policy effectiveness.\(^4\) On the other hand, Olivero, Li, and Jeon (2011) use bank-level data from ten Asian and ten Latin American countries and find that increased competition in the banking sector *weakens* the transmission of monetary policy.\(^5\) Khan, Ahmad, and Gee (2016) use bank-level data from 5 Asian countries and find that the connection between banks’ competition and monetary policy effectiveness crucially depends on the measures of bank competition. While an increase in competition is associated with more effective monetary policy when using some measures (CR5, HHI and Lerner Index), when using the Boone Indicator the results suggest that a *decrease* in the level of competition is associated with more effective monetary policy transmission. While the above studies mainly use structural and two non-structural measures of bank competition, in this paper I use changes in banks geographical restrictions in the U.S. to measure exogenous changes to banks’ competition.

Second, this paper is related to the literature which studies the effects of the financial deregulation process in the U.S., specifically the deregulation of the restrictions on banks geographic expansion.\(^6\) The first group of papers focus on the economic consequences of the deregulation process between 1970 to 1994. These papers have examined the connection between deregula-

\(^3\)See Beck, Colciago, and Pfajfar (2014) for an excellent review of the literature on banks’ role in the transmission of monetary policy.

\(^4\)Similar results are found by Brissimis, Delis, and Iosifidi (2014) for the U.S. and Euro area using bank-level data and different measures of banking competition (the Boone indicator and the Lerner index).

\(^5\)Similar results are found by Yang and Shao (2016) for the Chinese banking system.

\(^6\)See Kroszner and Strahan (2014) for an excellent historical review.
tion and economic growth (Jayaratne and Strahan 1996), economic volatility (Morgan, Rime, and Strahan 2004), income inequality (Beck, Levine, and Levkov 2010), investment efficiency (Acharya, Imbs, and Sturgess 2010), and bank valuations (Goetz, Laeven, and Levine 2013). This paper is more related to another group of papers which follow Rice and Strahan (2010) and use differences in state openness to interstate branching after the passage of the Riegle-Neal Interstate Banking and Branching Efficiency Act (IBBEA) in 1994 as an exogenous measure for banks competition (Favara and Imbs 2015; Celerier and Matray 2016; Keil and Müller 2017; Chu 2017). To the best of my knowledge, the connection between deregulation of the restrictions on entry and geographic expansion of financial intermediaries in the U.S. and the effectiveness of monetary policy has not yet been explored.

Finally, the paper is also related to the literature that examines the relationship between monetary policy and regional asymmetries in the U.S. (Cooper, Luengo-Prado, and Olivei 2016; Beraja et al. 2017; Albuquerque et al. 2017) and to the literature which uses cross-sectional regional variation in the U.S. to examine the key mechanisms which led to the Great Recession (Mian and Sufi 2009; Mian and Sufi 2010b; Goetz and Gozzi 2010; Mian and Sufi 2011; Liebersohn 2017).

2.2 Macroeconomic Models

This paper also fits with several strands of the literature which incorporate financial frictions in macroeconomic models.

First, the 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 and Moore (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 dividends maximizing banks. Gerali et al. (2010) also incorporate imperfect banking competition in a New Keynesian setup by assuming monopolistic competition in the banking sector (using a Dixit-Stiglitz framework) and sticky loan rates.

Second, the paper is related to research which studies the coordination and implementation of monetary and macroprudential policies in the context of DSGE models. This literature typically assumes that the banking sector is perfectly competitive (Rubio and Carrasco-Gallego 2016b; Tayler and Zilberman 2016; Collard et al. 2017; Gelain and Ilbas 2017; Kiley and Sim
or does not incorporate a banking sector (Beau, Clerc, and Mojon 2012; Lambertini, Mendicino, and Punzi 2013; Rubio and Carrasco-Gallego 2014; Bailliu, Meh, and Zhang 2015; Kolasa 2016; Alpanda and Zubairy 2017). However, there is significant evidence for the failure of perfect competition in the banking sector. Thus, this paper is more similar to the more realistic literature which incorporates an imperfect competitive banking system. For example, Angelini, Neri, and Panetta (2014) use a set-up similar to Gerali et al. (2010) to show that while time-varying capital requirements can improve macroeconomic stability, the benefits depend on the type of shocks and the degree of coordination with monetary policy. This paper differs from these studies by modeling imperfect competition in the banking sector using Andrés and Arce (2012) framework. The main reason for using this framework is that it allows for an endogenously-derived credit spread which fits the significant empirical evidence for the negative relationship between banking market power and lending spreads. Additionally, in this framework, the level of bank competition affects the responsiveness of macro-aggregates to monetary shocks. Thus, the model fits some of the key empirical facts regarding the U.S. economy in the run-up to the recent crisis documented in this paper.

Finally, 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 Rabanal 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. In these models, the sources of the cross-country/cross-region heterogeneity are set exogenously by using asymmetric shocks, different proportion of borrowers, heterogeneous mortgage contract

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7See Claessens (2009) for a review of the literature on banks market power and imperfect competition in the banking sector.

8Another 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. However, they do not include any prudential policy in their model.

9See Degryse and Ongena (2008) for a review of the literature.

10Midrigan and Philippon (2016) also use U.S. regional variation to investigate how liquidity constraints affect aggregate dynamics.
structures, differences in LTV ratio, and different leverage ratio. This study contributes to this literature by demonstrating the potential of using banks’ market power as an important source of regional variations when modeling a large country with different regions (U.S.), or a monetary union with different countries (E.U.). In such a framework the source of the cross-regional differences could be attributed to explicit financial sector competition policies.

3 Empirical Investigation

In this section, I will provide empirical evidence on how state level regulation and financial competition can shape the effectiveness of monetary policy.

3.1 Measuring Banks’ Competition

Empirical research on credit supply response to monetary policy and bank competition uses different indexes and measures such as the Herfindahl- Hirschman Index, the Lerner Index, and more to measure levels of competition (Olivero, Li, and Jeon 2011; Adams and Amel 2011; Fungáčová, Solanko, and Weill 2014; Leroy 2014; Yang and Shao 2016). However, these measures may suffer from endogeneity concerns such as both omitted variable bias and reverse causality. For example, aggregate fluctuations which affect the stance of monetary policy may also affect banks profitability, mergers, and markup which in turn affect the concentration/competition measures. Alternatively, changes and banks market power could affect economic aggregate economic activity and induce a change in the federal fund rate.

In this study, I use the introduction of the Interstate Banking and Branching Efficiency Act (IBBEA) in the U.S. as an exogenous change in banks’ competition. The IBBEA relaxed geographical restrictions to bank expansion across state borders. This relaxation enables banks to enter into new markets in other states thereby increasing the level of bank competition in the deregulated states. Following the deregulation, the banking sector became more consolidated but less locally concentrated. The deregulation has led to larger, better-diversified banks that compete in multiple markets and across larger geographical areas (Kroszner and Strahan 2014).

While the IBBEA basically eliminated the geographical limitation faced by banks, it gave states considerable decision power over the time and manner in which it was implemented (Rice and Strahan 2010). Following Rice and Strahan (2010), I use the timing of the deregulation in each state as an exogenous change to a state banking competition level. Specifically, I use Rice
and Strahan (2010) restriction on the interstate branching index. Their index runs from 1994 to 2005 and takes values between zero and four. They set the index to zero for states with no restrictions and add 1 for each type of restriction imposed (up to 4). I use this index to create a regulation dummy variable which is equal to zero if the state did not lift any restriction and switches to one when the state implemented any kind of state banking deregulation.11

The identification builds on the assumption that state-level deregulation is exogenous to changes in monetary policy. This assumption is supported by an extensive body of research which provides evidence that interstate bank deregulation is exogenous to local bank structure or local economic conditions (Jayaratne and Strahan 1996; Jayaratne and Strahan 1998; Kroszner and Strahan 2014; Goetz, Laeven, and Levine 2013; Goetz, Laeven, and Levine 2016). Additionally, this assumption is in line with a growing number of studies who use the passing of the IBBEA to test how exogenous shocks to banks competition affect firm financing (Rice and Strahan 2010; Francis, Ren, and Wu 2017), firm innovation (Cornaggia et al. 2015), bank lines of credit (Shenoy and Williams 2017) and bank fragility (Marsh and Sengupta 2017).

3.2 Data and Variable Construction

I use annual bank-level data from the Federal Reserve’s Report of Condition and Income (Call Reports), made available from Wharton Research Data Services (WRDS). I focus on state insured (rssd9424 = 1, 2, 6 or 7) commercial banks (rssd9048 = 200) since branching deregulation only covered depository institutions and within depository institutions themselves, only federal and state-chartered commercial banks (Favara and Imbs 2015).

I follow Ashcraft and Campello (2007) and exclude any bank-year observation in any year where the bank is involved in a merger.12 Additionally, I use only banks with positive values for total assets and loans and eliminate any bank-year observation with loan-growth exceeding five standard deviations from the annual mean. Finally, I limit to banks having at least three consecutive years of data. Banks are identified as part of a holding company using the bank’s topmost BHC identity (rssd9348). Details about the formation of all bank level variable using the Call Reports data are given in Appendix A.3.

I link the bank-specific information with state-level macroeconomic information obtained

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11Using this kind of dummy variable is in line with Chava et al. (2013), Keil and Müller (2017), and D’Acunto et al. (2017).
12To identify mergers and acquisitions, I use the most recent merger file from the Federal Reserve Bank of Chicago.
from a number of sources: state-level unemployment from the Bureau of Labor Statistics (BLS), state-level house price index from the Federal Housing Finance Agency (FHFA), per capita income from Bureau of Economic Analysis (BEA), and state-level per capita total debt balance from NYFED Center for Microeconomic Data.

The full sample includes 10,870 banks with a total of 78,115 bank-year observations over the period of 1994-2005. Descriptive statistics for the main variables used in the estimations are presented in Table 2. Variables are in line with other studies using call report data and bank balance sheet information.\textsuperscript{13}

### 3.3 Empirical Specification

The baseline model I use builds on existing papers which study monetary policy effectiveness using annual bank-level data.\textsuperscript{14} In order to investigate the possible interactions between monetary policy and branching deregulation I estimate the following equation:

$$
\Delta \ln (loans)_{i,j,t} = \alpha_j + \alpha_t + \beta_1 \Delta \ln (loans)_{i,j,t-1} + \beta_2 \Delta MP_t + \beta_3 D_{j,t} + \beta_4 \Delta MP_t * D_{j,t} + \beta_5 X_{i,t-1} + \beta_6 Z_{j,t} + \varepsilon_{i,j,t}
$$

where $i$, $j$ and $t$ denotes banks, states, and years, respectively. $\Delta \ln (loans)_{i,j,t}$ is the annual growth rate of loans in period $t$ of bank $i$ headquartered in state $j$. $MP$ is the monetary policy stance. In the baseline estimation, I use the effective federal funds rate as the indicator for monetary policy.\textsuperscript{15} $D_{j,t}$ is a dummy variable that equals one if restrictions on intrastate branching are lifted in year $t$ in the state where bank $i$ is headquartered. This dummy variable is interacted with the policy variables to investigate the marginal effect of policy on loan growth following branching deregulation.

Previous studies have documented that bank-specific characteristics may influence the effectiveness of monetary policy.\textsuperscript{16} I follow the literature and add a vector of bank-specific controls,

\textsuperscript{13}See for example Ashcraft and Campello (2007), Table 2.


\textsuperscript{15}While there is no consensus as to the best indicator of monetary policy stance, most studies use short-term market interest rates, such as the federal funds rate to measure policy action. The results are qualitatively the same when using the Romer and Romer (2004) measure of the exogenous component of monetary policy. Results for the Romer and Romer (2004) measure are available upon request.

\textsuperscript{16}See for example Kashyap and Stein (2000) and Kishan and Opiela (2006) among many others.
$X_{i,t-1}$, that includes banks’ size, liquidity, and capitalization. Size is measured by the log of total assets, liquidity is defined as the ratio of liquid assets to total assets, and capitalization is given by the ratio of bank capital to total assets. Bank specific characteristics are lagged one period to reduce endogeneity concerns. All banks are analyzed on the charter bank and not on the bank holding company level. Ashcraft (2006) show that banks that are affiliated with a bank holding company are less sensitive to changes in monetary policy relative to unaffiliated banks. Thus, I also add a dummy variable equal to one if the bank is affiliated with a bank holding company. $Z_{j,t}$ is a vector of state-specific macroeconomic control variables that control for cross-sectional differences in demand between states. Following Favara and Imbs (2015), $Z_{j,t}$ includes the state level log change in income per capita, unemployment and house prices. Standard errors are clustered at the bank level to account for potential serial correlation.

The key variable of interest in Equation 1 is $\beta_4$, the coefficient on the interaction between the measure of monetary policy and the state level regulation dummy. Significant levels of $\beta_4$ indicate that, holding all else equal, banks located in deregulated states react differently to monetary policy (in term of change in the supply of credit) relative to banks located in regulated states.

For robustness, I extend the estimation of Equation 1 in a number of ways. First, following Ashcraft (2006) and Altunbas, Gambacorta, and Marques-Ibanez (2009), I add interactions between changes in monetary policy and bank characteristics. Second, I estimate the model with state-specific fixed effect, $\alpha_j$, to control for any time-invariant state-specific factors that are not accounted for by the control variables. Third, I add time fixed effect, $\alpha_t$ to control for time-varying factors that are common to all banks.

### 3.4 Results

Table 3 presents the results of estimating Equation 1. The first column reports the results for the baseline specification. The other columns present the results for the alternative specification which include interaction terms between bank controls and monetary policy (column 2), state fixed effect (column 3), time effect (columns 4), and both together (column 5).

The coefficient on the interaction between monetary policy and deregulation is statistically significant and negative across all specifications except column 4. The negative coefficient indicates that after the branching deregulation, banks display more contraction in loan supply.

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17See Appendix A.3 for variable construction and specification.
following contractionary monetary policy. That is, banks become more sensitive to changes in the policy rate.

The positive and significant coefficients of the deregulation dummy indicate an expansion of credit following deregulation consistent with the findings of Favara and Imbs (2015). In column 1 the positive coefficient for a change in monetary policy may seem puzzling since the positive responsiveness is not of the expected sign. The positive coefficient could be attributed to the lack of time fixed effect or the lack of interaction between the policy stance and bank-specific controls in the baseline specification (Ashcraft 2006; Kishan and Opiela 2006). All other results are in line with the literature on banking and monetary policy.

4 Model

The previous section established that monetary policy effectiveness is related to banking regulation and specifically regulation that affects banks’ competition. In this section, I develop a model that can match some of the key features presented in the introduction and in the empirical section.

4.1 Model Setup

The starting modeling framework is an infinite-horizon, discrete-time, New Keynesian model following Andrés, Arce, and Thomas (2013) (henceforth 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 policymakers should respond to financial imbalances.

The model features the following agents: (i) a measure one of infinitely lived patient households, (ii) a measure one of infinitely lived impatient households (entrepreneurs), (iii) a continuum of monopolistically competitive final goods firms (retailers) 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
and Moore (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 Patient Households

Households choose consumption, housing, and work hours to maximize a lifetime utility function subject to a budget constraint.\(^{18}\) Assuming all households are identical the representative household maximize:

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

subject to:

\[
d_t + c_t + q_t(h_t - h_{t-1}) = div_t + f_t + w_t l_t^s + \frac{R^D_{t-1}d_{t-1}}{\pi_t} \tag{3}
\]

where \(c_t, h_t\) and \(l_t^s\) represents consumption goods, housing stock, and hours of work supplied by household at time \(t\). \(\beta\) is the patient household discount factor. \(\frac{1}{\varphi}\) is the Frisch labor supply elasticity. \(j\) is the weight of housing in the utility function. \(d_t\) 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 good firms and banks respectively, assumed to be owned by households (both in real terms). \(w_t\) is the real wage rate. \(R^D_{t-1}\) is the riskless nominal return on deposits between period \(t-1\) and \(t\).\(^{19}\) Finally, \(\pi \equiv \frac{P_t}{P_{(t-1)}}\) is the gross inflation rate.

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

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

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

\[
\frac{1}{c_t} = \beta P_t^{D} E_t \left[ \frac{1}{c_{t+1} \pi_{t+1}} \right] \tag{6}
\]

\(^{18}\)The budget constraint is expressed in real terms.

\(^{19}\)Following Iacoviello (2005), I assume that debt contracts are set in nominal terms and are not indexed to inflation.
4.3 Impatient Households (Entrepreneurs)

Entrepreneurs use real estate and household labor to produce an intermediate good $y_t$ that they sell to final good producers in a perfectly competitive market at a price $P_t^f$. Assuming a Cobb-Douglas constant return to scale production function:\textsuperscript{20}

$$y_t = A_t (h_t^d)^{1-\alpha} (l_{t-1})^{\alpha}$$  \hspace{1cm} (7)

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

$$\log A_t = \rho_A \log(A_{t-1}) + e_{A,t}$$  \hspace{1cm} (8)

and $e_{A,t} \sim N(0, \sigma_A^2)$ 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 $\kappa$ is the utility cost per distance units. A representative entrepreneur thus maximizes:

$$E_0 \sum_{t=0}^{\infty} (\beta^e)^t (\log c^e_t - \kappa \delta^k_i)$$  \hspace{1cm} (9)

s.t.:

$$c^e_t + q_t (h^c_t - h^e_{t-1}) + \frac{R_{t-1}^{B} b_{t-1}}{\pi_t} = \frac{y_t}{x_t} - w_t l^d_t + b_t$$  \hspace{1cm} (10)

$$b_t \leq m_t E_t \left[ \frac{q_{t+1} h^e_{t+1} \pi_{t+1}}{R^{B}_{t+1}} \right]$$  \hspace{1cm} (11)

Equation 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 good over intermediate good, which is equal to $\frac{P_t}{P_t^f}$, where $P_t$ is the final good price index and $P_t^f$ is the nominal price of the intermediate goods. Thus, $\frac{1}{\pi_t}$ is the real price of the intermediate goods (or the marginal cost of the final goods). $c^e_t$, $h^c_t$ and $l^d_t$ represent consumption goods, housing stock, and hours of work demanded by entrepreneurs at time $t$.

$\beta^e$ is the entrepreneurs’ discount factor, with $\beta^e < \beta$. Following Kiyotaki and Moore (1997), entrepreneurs face collateral constraint on the amount they can borrow each period, which is

\textsuperscript{20}I assume a continuum of impatient households of mass 1, indexed by $k$. Symmetry across firms and flexible prices allow me to write the production of $y_t$ without the index $k$. 

14
expressed by Equation 11. That is, borrowers cannot borrow more than a fraction \(m\) of the expected value of their real estate stock. Thus, \(m\) 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.\(^{21}\) Here, on the other hand, a regulator controls the LTV ratio which adds macroprudential policy to the model (see Section 4.6.1).

The first order conditions for the impatient households are:

\[ w_t = \frac{y_t(1 - \alpha)}{x_t l_t^d} \quad (12) \]

\[ 1 \frac{c_t^e}{c_{t+1}^e} = \beta^e R^B_t E_t \left[ \frac{1}{c_{t+1}^e + x_{t+1} h_t^e + q^{t+1}} \right] + \lambda_t^e \quad (13) \]

\[ q_t \frac{c_t^e}{c_{t+1}^e} = E_t \beta^e \left[ \frac{y_{t+1}^{x_{t+1} h_t^e + q^{t+1}}}{x_{t+1} h_t^e + q^{t+1}} \right] + \lambda_t^e m_t E_t \left[ \frac{\pi_{t+1} b_t \pi_t}{R^B_t} \right] \quad (14) \]

where \(\lambda_t^e\) 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 worth denoted by \(nw_t^e\):\(^{22}\)

\[ c_t^e = (1 - \beta^e)nw_t^e \quad (15) \]

where \(nw_t^e\) is defined as:

\[ nw_t^e \equiv \frac{y_t}{x_t} + q_t h_t^e - \frac{R^B_t b_t}{\pi_t} - w_t l_t^d \quad (16) \]

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 Good Firms

There is a continuum of monopolistically competitive final goods firms of mass 1, indexed by \(z\), which are owned by patient households. Final good firms buy the intermediate good \(y_t\) in a perfectly competitive market at price \(P^I_t\). They turn the intermediate good to a final good

\(^{21}\)Others such as Iacoviello (2005) use a fixed LTV ratio.

\(^{22}\)See derivation in Appendix A.1.
\( y_t^f(z) \) 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:

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

(17)

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

\[
y_t^f(z) = \left( \frac{P_t(z)}{P_t} \right)^{-\varepsilon} y_t^f
\]

(18)

and the price index is given by:

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

(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 good firm to set price optimally. When the final good 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:

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

(20)

(21)

where \( mc_t \) is the firms’ real marginal cost (identical across all firms) which is equal to \( \frac{P_t^f}{P_t} \) or the inverse of the markup, \( x_t \). Using \( \frac{1}{x_t} \) as the real marginal cost, Equation 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:

\[
P_t^* = \frac{\epsilon}{\epsilon - 1} \frac{E_t \sum_{i=0}^{\infty} (\theta \beta)^i \frac{1}{c_{t+i}} \frac{1}{x_{t+i}} y_t^f(z) \left( \frac{1}{P_{t+i}} \right)^{-\varepsilon}}{E_t \sum_{i=0}^{\infty} (\theta \beta)^i \frac{1}{c_{t+i}} y_t^f(z) \left( \frac{1}{P_{t+i}} \right)^{1-\varepsilon}}
\]

(22)

I can write this expression as

\[
P_t^* = \frac{\epsilon}{\epsilon - 1} \frac{g_{1,t}}{g_{2,t}}
\]

(23)
where

\[ g_{1,t} = \frac{1}{c_{t+i}} P_t^e y_t^f + \theta \beta E_t g_{1,t+1} \]  \hspace{1cm} (24)

\[ g_{2,t} = \frac{1}{c_{t+i}} P_t^{e-1} y_t^f + \theta \beta E_t g_{2,t+1} \]  \hspace{1cm} (25)

The aggregate price level than satisfies:

\[ P_t = \left[ \theta P_{t-1}^{1-\varepsilon} + (1 - \theta)(P_t^*)^{1-\varepsilon} \right] \frac{1}{1-\varepsilon} \]  \hspace{1cm} (27)

Finally, total real profits in the final good 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. Patient household supply funds (deposits) that pay a nominal gross rate \( R_D^P \). Banks are perfectly competitive on 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 \( R_B^P \).

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.\(^{23}\) Bank \( i \in 1, 2, \ldots, n \) then chooses \( R_B^P(i) \) to maximize:

\( \text{AAT assume that individual entrepreneurs location changes every period according to an } i.i.d \text{ process in order to eliminate strategic interaction between specific banks and specific borrowers.} \)
\[
E_t \sum_{\tau=0}^{\infty} \beta^\tau \frac{c_t}{c_{t+\tau}} \text{div}(i)_{t+\tau} = 0
\]

s.t.:
\[
div(i)_t + \frac{R^D_{t-1}d_{t-1}(i)}{\pi_t} + b_t(i) = \frac{R^B_{t-1}(i)b_{t-1}(i)}{\pi_t} + d_t(i)
\]
\[
d_t(i) = b_t(i)
\]

where \(\beta^\tau \frac{c_t}{c_{t+\tau}}\) is the stochastic discount factor of the patient households at time \(t + \tau\) and \(\text{div}(i)_t\) are the bank’s profits in real terms. Equation 29 is the banker flow of funds constraint (in real terms), and (30) is the balance sheet identity, so that (29) can be reduced to:

\[
div(i)_t = (R^B_{t-1}(i) - R^D_{t-1}) \frac{b_{t-1}(i)}{\pi_t}
\]

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 \(R^B_t(i)\) then gives:

\[
R^B_t(i) = R^D_t + \frac{1}{\partial R^B_t(i) / b_t^k(i) - \partial R^B_t(i) / b_t^*(i)}
\]

From (32) 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 \(R^B_t\), the optimal interest rate margin is:

\[
R^B_t - R^D_t = \frac{R^D_t - m_t E_t \left( \frac{q_{t+1}}{q_t} \right) R^D_t}{\eta m_t E_t \left( \frac{q_{t+1}}{q_t} \right) - R^D_t}
\]

where

\[
\eta = 1 + \frac{n}{\kappa} \frac{\beta^e}{1 - \beta^e}
\]

The degree of banking competition is captured by the ratio of \(\frac{n}{\kappa}\). As we can see from (33), in this setup the lending spread is decreasing in the level of bank competition. It is important

\[\text{See full derivation in Appendix A.2}\]
to note that according to (33) the lending spread is also decreasing in the LTV ratio \( m_t \) and the expected increase in housing prices, \( E_t \left( \frac{q_{t+1}}{q_t} \right) \), 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 main contribution to AAT model is adding a regulator which sets the LTV ratio according to some 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 suggest that large credit expansions tend to lead to financial crises (Drehmann, Borio, and Tsatsaronis 2011; Bakker et al. 2012; Schularick and Taylor 2012; Babecyk 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:

\[
m_t = m_{ss} \left( \frac{b_t}{b_{ss}} \right) - \phi_m e_{m,t} \tag{35}\]

where \( m_{ss} \) is a steady state value for the loan-to-value ratio, \( b_{ss} \) is the steady state level of debt, and \( \phi_m \) is a measure of the responsiveness of the loan-to-value deviation of credit from steady-state levels. \( u_{m,t} \) follows an AR(1) process, \( u_{m,t} = \rho_m u_{m,t-1} + \epsilon_{m,t} \), where \( \epsilon_{m,t} \sim N(0, \sigma^2_m) \) is an i.i.d credit supply shock (financial shock). 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:

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

(36)

where $R_{ss}, \pi_{ss}, Y_{ss}$ are steady state interest rate, inflation and output. $\phi_R, \phi_{\pi}, \phi_Y$ are policy response coefficients. $e_{R,t} \sim N(0, \sigma_{R}^2)$ is i.i.d monetary policy shock.

4.6.3 Leaning Against the Wind Monetary Policy (LATW)

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 lean against build-ups of financial imbalances by changing the policy interest rate in response to deviations of credit from its steady-state value:

$$\frac{R_t}{R_{ss}} = \frac{R_{t-1}}{R_{ss}} \phi_R \left( \left( \frac{\pi_t}{\pi_{ss}} \right)^{1+\phi_{\pi}} \left( \frac{Y_t}{Y_{ss}} \right)^{\phi_Y} \left( \frac{b_t}{b_{ss}} \right)^{\phi_B} \right)^{1-\phi_R} e^{u_{m,t}}$$

(37)

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 $\{c_t, c_t^f, f_t, div_t, h_t, h_t^e, l_t, d_t, b_t\}$ that for some exogenous process $\{e_{A,t}, e_{m,t}, e_{R,t}\}$ 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:

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

(38)

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

$$l_t^s = l_t^d$$

(39)

- 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:

$$1 = h_t + h_t^e$$

(40)
• In the financial market the total supply of funds by households is equal to the total demand by entrepreneurs:

\[ b_t = d_t \]  

(41)

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. For calibration, 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. \(^{25}\) The weight on housing in the utility, \( j \), the inverse of the Frisch elasticity, \( \varphi \), the share of housing in the production, \( \alpha \), and the steady-state LTV ratio, \( m \), are set at 0.12, 1, 0.05, 0.8 respectively. The elasticity of substitution across goods, \( \varepsilon \), 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 credit shock (not estimated in Iacoviello and Neri (2010)) are set to \( \rho_m = 0.75 \) and \( \sigma_m = 0.018 \), following AAT. The parameters are shown in Table 4.

A key non-standard feature of the calibration is the ratio \( n/\kappa \) which determines the steady state lending spread and is used as a proxy for the level of banks’ market power.\(^{26}\) I compare two different levels of banks’ market power. First, I consider an environment where banks have no market power such that \( R^D = R^B \) (i.e. \( \kappa = 0 \), 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 US between 1987 to 2003 were typically in the range of 200-298 basis points. For the case of an imperfectly competitive banking sector, I then calibrate \( n/\kappa \) so that in steady state the annual

\(^{25}\)See Iacoviello (2005) for a discussion.

\(^{26}\)This is consistent with empirical evidence which shows that, all else being equal, stronger competition in the banking sector is associated with significantly lower loan spreads (Degryse and Ongena 2008; Van Leuvensteijn et al. 2013).
loan spread will equal the upper range implied by the data (3%).

5.2 Impulse-Response Analysis: Baseline Policy Regime

In this subsection, I use impulse response analysis to analyze how the level of banks’ market power affects the aggregate response to key shocks. I compare the reaction in the benchmark model (i.e., standard Taylor rule without macroprudential) under perfect and imperfect competitive banking sector. This section is intended to show that the baseline model performs as expected by the empirical part. The overall results are qualitatively in line with Andrés and Arce (2012) and Andrés, Arce, and Thomas (2013).

For the baseline simulation, I fix the policy coefficients in the monetary policy reaction function following Justiniano, Primiceri, and Tambalotti (2015). I set the smoothing parameter, \( \phi_R = 0.8 \), the policy reaction to output, \( \phi_Y = 0.125 \), and the policy reaction to inflation, \( 1 + \phi_\pi = 2 \). According to Justiniano, Primiceri, and Tambalotti (2015), these policy coefficients are in line with empirical estimations of the Taylor rule in the US after 1984.

Figures 5 to 7 present the impulse response functions of some key variables to a monetary, technology and credit shock. All responses are to a one standard deviation temporary shock. Figure 5 displays the reactions following a 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. Regarding the effect of bank competition, the figure shows that the response of all variables to the monetary shock is weaker when banks have more market power. AAT explain this weaker reaction to a monetary shock when banks have market power by showing that an increase in banks competition is associated with an increase in entrepreneurs leverage. Higher leverage then amplifies the effect of the shock by negatively affecting housing prices and entrepreneurs ability to borrow. Overall, Figure 5 suggests that a more competitive banking sector is associated with a more effective monetary policy, especially regarding the effect on output and debt. This result is in line with the finding presented in the empirical section (Section 3).

Figure 6 shows the response to a positive technological shock (unanticipated increase in \( A \)). As before, the effect on all variables is stronger in the economy with a perfectly competitive

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27This level of loan spread is in general line with levels used by 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).
banking sector. However, the differences are much smaller relative to the monetary shock.

The main reason is that a technology shock affects inflation and housing prices in the opposite
direction. From Equation 11 we can see that a technology shock, which increases house prices
but reduces expected inflation, will have opposite effects on entrepreneurs borrowing ability.
Smaller changes in entrepreneurs borrowing ability tend to make the overall impact of the
shock much smaller. In Figure 7 we can see the response following an expansionary credit
shock (unanticipated increase in the LTV ratio, $m$). The shock leads to a rise in output,
house prices, total debt and households consumption and a fall in the inflation rate. Different
from the case of a monetary and technological shock, the effect of the credit shock seems to
be stronger for the economy with the imperfect competitive banking sector. While output,
house prices, and household consumption increase more on impact in the perfectly competitive
economy, the overall effect is more persistent in the imperfect competitive banking economy.
Inflation also seems to be more affected in the imperfect competitive although the difference is
very small. The effect on debt is almost identical under the two levels of banks competition.

The economic intuition behind the different reaction of some variables to a credit shock is that
the lending spread is a function of the LTV ratio, $m$ (see Equation 33), and is hence directly
affected by the change in the LTV ratio. In the imperfect competitive banking sector case, the
effect of a shock to $m$ is amplified by an additional change to the lending spread on top of the
initial change in $m$ which further affects the cost of borrowing. Thus, under imperfect banking
competition, the lending spread reacts countercyclically to the credit shock and amplifies the
overall effect.\footnote{See Andrés and Arce (2012) Sections 4.1 and 4.2 for an in-depth discussion on the channels and transmission of the monetary and credit shock in a similar modeling environment with an imperfect competitive banking sector.}

5.3 Comparing Policy Regimes

I investigate if the level of banks’ competition affects the behavior of the estimated economy
under the three different policy regimes presented in Section 4.6. I consider the three policy
regimes under two levels of banks’ competition, perfect and imperfect, and compare how key
variables react to different shocks. The policy coefficients in the standard Taylor rule are
set as in the basic calibration describes in Section 5.1. The policy coefficient on debt in the
macroprudential policy rule and the augmented Taylor rule, $\phi_b = 0.3$, is set following Kannan,
To illustrate how banks’ market power may affect the optimal use of monetary and macroprudential policies, I will first focus the analysis on a positive technology shock (supply shock) which is considered one of the most important sources of business cycle fluctuations in the DSGE literature. Figures 8 presents the dynamic response of the model following a positive technology shocks under the alternative policy regimes and perfect and imperfect competitive banking sector. Relative to the benchmark regime (i.e., only standard Taylor rule) a macroprudential rule reduces the fluctuations and the magnitude of the response of all variables following the shock. The countercyclical macroprudential rule is especially successful in mitigating the credit boom. This suggests that following a supply shock, countercyclical macroprudential regulation can reduce the trade-off between output and inflation stabilization.

In a policy regime that combines a macroprudential rule and LATW monetary policy, the impact of a technological shock on output, debt and house price is further mitigated. On the other hand, inflation falls by more under the combined policy regime. The economic intuition for the stronger fall in inflation is as follows: In both cases, the central bank eases monetary policy in response to the fall in inflation resulting from the positive technology shock. However, 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 reduce their demand for credit and housing. As a result, housing prices increase by a smaller magnitude and borrowers’ financing conditions improving significantly less (highlighted by the stronger fall in the loan rate in the benchmark case).

These patterns highlight an important policy 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 volatility and perhaps promote financial stability. On the other hand, the aggressive response to credit expansion amplifies the volatility of the inflation rate and increases the output-inflation trade-off.

Regarding the difference between a perfect and imperfect competitive banking sector, the responses in the two regimes where policymakers react to credit growth are relatively similar across levels of bank competition. However, under the benchmark case, the impact of the technology shock is dampened when the banking sector is imperfectly competitive. The most significant difference is the reaction of total debt which rises by much less in the imperfect competitive economy relative to the perfect competition case. This suggests that concerning volatility, an imperfectly competitive banking sector can reduce the trade-offs between output,
inflation and financial condition.

Table 5 further shows the volatility trade-off described above. The table shows the volatility of the four target variables under different combinations of policy regimes and banks competition. While the lowest levels of volatility for output, housing prices, and debt is under the combined macroprudential-LATW regime, it also has the highest levels of inflation volatility, even relative to the benchmark case. The volatility of all variables and the magnitude of the difference between the three cases drop when the banking sector is imperfectly competitive. Overall the results seem to favor the idea that there is a trade-off between bank competition and financial stability. Thus, the results point to possible benefits from adding banks’ competition to policymakers consideration when studying the use of monetary and macroprudential policies.

5.4 Key Issues and Extensions

While the above result suggests an interaction between monetary, macroprudential policies and banks’ market power, some limitations and essential extensions should be acknowledged.

First, results are obtained under a single shock (a supply shock). As shown by Kannan, Rabanal, and Scott (2012) the optimal use of monetary and macroprudential policies may depend on the source of the disturbance.29 Thus, a crucial first extension is to add to the analysis a set of other calibrated shocks.

Second, The above results may depend on the values of the policy parameters chosen somewhat arbitrarily. Additionally, I do not consider the possible effects of coordination between macroprudential and monetary policy. Angelini, Neri, and Panetta (2014) show that lack of coordination between a macroprudential authority and the central bank may cause conflicting policies.30 An additional important extension is then to specify a policy objective function and use it to check how banks competition shape the optimal combination of policy parameters.

Finally, the above simulation is not able to quantify any potential gains (or losses) from having an imperfectly competitive banking sector. Assuming policymakers have some control over the level of banks market power, there may be additional benefits from targeting an optimal level of banks market power which is coordinated with policymakers objectives and the policy coefficients. To illustrate the possible benefits of coordinating monetary policy with

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29 Similar conclusions are also found by Angelini, Neri, and Panetta (2014) and Tayler and Zilberman (2016).

30 These conflicting policies are also known as the "pull me-push you" interaction (Bean et al. 2010).
macroprudential regulation and the level of bank competition a possible extension would be to use an efficiency frontier (Taylor curve) that includes the objectives of the policymakers (for example variability of output, inflation, and debt) and use it to analyze what is the policy regime-bank competition combination that can deliver the most stable/socially optimal environment.\textsuperscript{31}

6 Summary

This paper presents an empirical and theoretical investigation on the role of local financial supply conditions in the transmission and optimal use of monetary and macroprudential policies. Using the deregulation of interstate branching in the U.S. as a "quasi-natural experiment" I provide empirical evidence for the negative relationship between banks' market power and monetary policy effect on banks credit supply. These results add to the growing literature which relates local financial conditions with variations in the state-level reaction to the Great Recession.

Macro models which try to estimate the proper policy reaction to buildups of financial vulnerability have generally ignored these cross-state variations and the importance of banks’ market power. Thus, in the second part of the paper, I presented a benchmark model which could be used to investigate what banks’ market power imply for the use of monetary and macroprudential policies. Using impulse response functions (IRFs), I show that the level of competition in the financial system substantially affects the response of the economy to monetary and credit shocks. I then examine the behavior of the economy under the three different policy regimes presented in Section 4.6. That is, I study the reaction to a technology shock when monetary and macroprudential policies change according to the different rules and policy objectives. Overall, the results highlight how considering financial conditions interaction with monetary and macroprudential policies may enhance economic stability.

\textsuperscript{31}See Gambacorta and Signoretti (2014), Rubio and Carrasco-Gallego (2014), and Taïler and Zilberman (2016) for examples of using an efficiency frontier in the context of using optimal policy to promote financial stability.
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A Appendix

A.1 Derivation of Entrepreneurs Consumption

Define \( \psi_t \equiv m_t E_t \left[ \frac{q_{t+1} \pi_{t+1}}{R^B} \right] \) so that Equation 11 could be written as

\[
b_t = \psi_t h^e_t
\]

Then using Equations 13 and 14 from the entrepreneurs maximization problem we get:

\[
\frac{q_t - \psi_t}{c^e_t} = \beta^e E_t \left[ \frac{\alpha \psi_{t+1} h_t^e + q_{t+1} - R^B_t \psi_{t+1}}{c^e_{t+1}} \right]
\]

using (12) and (42) I can rewrite the definition of real net worth (Equation 16) as:

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

Now, recall that according to (15), every period entrepreneurs consume a constant fraction from their \( nw^e_t \):

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

using (15) and (44) in (43) I get:

\[
\frac{q_t - \psi_t}{c^e_t} = \beta^e E_t \left[ \frac{nw^e_{t+1} h^e_t}{(1 - \beta^e) nw^e_{t+1}} \right]
\]

using (42) and (44) I can rewrite the entrepreneurs budget constraint (Equation 10) as

\[
c^e_t + q_t h^e_t = \psi_t h^e_t + \frac{y_t}{x_t} - w_t l^d_t + q_t h^e_{t-1} - \frac{R^B_{t-1} b_{t-1}}{\pi_t}
\]

simplifying (45) to:

\[
q_t h^e_t - \psi_t h^e_t - \beta^e q_t h^e_t + \beta^e \psi_t h^e_t - \beta^e c^e_t = 0
\]
and using (46) in (47) gives

\[ n u_t^e - c_t^e - \beta^n w_t^e = 0 \]  

(48)

which verifies that (15) holds.

### A.2 Derivation of Banks Lending Spread

I present the derivation of the optimal spread between the deposit rate and the loan rate, Equation 33. I build heavily of the proof presented in the technical appendix of Andrés and Arce (2012).

I start by rewriting (32) as:

\[ R_t^B(i) = R_t^D + \frac{1}{\Omega^k_t + \Omega^*_t} \]

(49)

where \( \Omega^k_t \equiv -\frac{\partial b^k_t(i)}{\partial R_t^B(i)} \frac{1}{b^k_t(i)} \) and \( \Omega^*_t \equiv -\frac{\partial b^*_t(i)}{\partial R_t^B(i)} \frac{1}{b^*_t(i)} \).

To find \( \Omega^k_t \), I first use the entrepreneur budget constraint, Equation 10, and the definition of \( n w_t^e \), Equation 16, in (15) to get:

\[ q_t h_t^e - b^k_t(i) = \beta^n n w_t^e \]

(50)

Using the entrepreneur borrowing constraint, Equation 11, in (50), I can express the demand for loans of entrepreneur \( k \) from bank \( i \) at time \( t \) as:

\[ b^k_t(i) = \beta^n n w_t^e \frac{\beta^n n w_t^e}{q_t \left[ \frac{R_t^B(i)}{m_t E_t(q_t \pi_{t+1})} \right] - 1} \]

(51)

I can then use (51) to get

\[ \Omega^k_t = -\frac{\partial b^k_t(i)}{\partial R_t^B(i)} \frac{1}{b^k_t(i)} \]

\[ = \frac{q_t \beta^n n w_t^e m_t E_t(q_t \pi_{t+1})}{[q_t R_t^B(i) - m_t E_t(q_t \pi_{t+1})]^2} \frac{1}{b^k_t(i)} \]

(52)

From (11) I can use \( m_t E_t(q_t \pi_{t+1}) = b^k_t(i) R_t^B(i)/h_t^e \) and after some algebra, (52) simplifies to:

37
\[ \Omega_t^k = \frac{1}{R_t^B(i) - \frac{m_t}{q_t}(q_{t+1} \pi_{t+1})} \] (53)

The next step is to find \( \Omega_t^* \). 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 fund 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:

\[ E_t \left[ \beta^e \log{c_{t+1}^e} \right] - \kappa \delta_{t}^{k,i} = E_t \left[ \beta^e \log{c_{t+1}^{e,i+1}} \right] - \kappa \delta_{t}^{k,i+1} \quad \forall t \] (54)

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 every period \( t \), the entrepreneur consumes a constant fraction of her net worth, \( nw_t^e \), which does not depend on the current banking choice (Equation 15). Thus, in (54) the optimal levels of consumption at time \( t+1 \) is the same when obtaining a loan at time \( t \) from bank \( i \) (\( \log{c_{t+1}^{e,i}} \)) or bank \( i+1 \) (\( \log{c_{t+1}^{e,i+1}} \)).

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 \( \delta_{t}^{k,i+1} = \frac{1}{n} - \delta_{t}^{k,i} \). Using this distance measure and (15) I can rewrite (54) as:

\[ \frac{\beta^e}{1 - \beta^e} E_t \left[ \log{n w_{t+1}^e} - \log{n w_{t+1}^{e,i+1}} \right] = \kappa \left( 2\delta_{t}^{k,i} - \frac{1}{n} \right) \] (55)

solving for \( \delta_{t}^{k,i} \):

\[ \delta_{t}^{k,i} = \frac{1}{2n} + \frac{1}{2\kappa \left( 1 - \beta^e \right)} E_t \left[ \log{n w_{t+1}^e} - \log{n w_{t+1}^{e,i+1}} \right] \] (56)

Equation 56 could be interpenetrated as the area where any located entreprenuers 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 \( i \):

\[ b_t^*(i) = \frac{1}{n} + \frac{1}{2\kappa \left( 1 - \beta^e \right)} E_t \left[ 2 \log{n w_{t+1}^e} - \log{n w_{t+1}^{e,i+1}} - \log{n w_{t+1}^{e,i-1}} \right] \] (57)
Using the definition of $nw_t^e$ (Equation 15), the entrepreneurs budget constraint (Equation 10), and the collateral constrain (Equation 11), I can express the entrepreneur net worth at time $t+1$ when taking a loan from bank $i$ at time $t$ as:

$$nw_{t+1}^e, i = \beta e^{\alpha \frac{y_{t+1}}{x_{t+1} h_{t+1}}} + q_{t+1} - m_t \frac{E_t(q_{t+1} \pi_{t+1})}{\pi_{t+1}} - m_t E_t(q_{t+1} \pi_{t+1}) \pi_{t+1}$$  \hspace{1cm} (58)

Using (58) and (57) I can find:

$$\Omega_t^* = \frac{n \beta e^{\kappa (1 - \beta e)}}{\kappa (1 - \beta e)} \left[ \frac{m_t E_t \left( \frac{y_{t+1}}{q_t} \pi_{t+1} \right)}{R_t E_t \left( \frac{y_{t+1}}{q_t} \pi_{t+1} \right)} \frac{R_t B}{R_t^B} \right]$$  \hspace{1cm} (59)

where I also use the fact that in equilibrium $\frac{1}{h(i)} = n \forall i$, 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 (53) and (59) in (49), which gives the equation for the optimal interest rate margin (Equation 33).
## A.3 Data and Variables Definition

### Table 1: Data and Variables Definition

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<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Source</th>
</tr>
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<tr>
<td>Loans</td>
<td>Gross total loans and leases. Series: rcon1400</td>
<td>Call Reports</td>
</tr>
<tr>
<td>Size</td>
<td>Logarithm of total assets. Series: rcfd2170</td>
<td>Call Reports</td>
</tr>
<tr>
<td>Capitalization</td>
<td>Ratio of equity capital to total assets. Series: rcfd3210/rcfd2170</td>
<td>Call Reports</td>
</tr>
<tr>
<td>Liquidity</td>
<td>Banks liquidity ratio Series: (rcfd1754 + rcfd1773 + rcfd1350 + rcfd3545)/rcfd2170</td>
<td>Call Reports</td>
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<tr>
<td>BHC</td>
<td>Dummy equals one if bank is part of BHC. Series: rssd9348</td>
<td>Call Reports</td>
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<tr>
<td>PerCapitaIncome</td>
<td>State level per capita personal income (dollars)</td>
<td>BEA (SA1)</td>
</tr>
<tr>
<td>Unemployment</td>
<td>State level unemployment, not seasonally adjusted</td>
<td>BLS</td>
</tr>
<tr>
<td>HPI</td>
<td>State level house price index, all-Transactions Indexes.</td>
<td>Federal Housing Finance Agency (FHFA)</td>
</tr>
<tr>
<td>Total debt</td>
<td>State level total debt balance per capita</td>
<td>NY FED Center for Microeconomic Data</td>
</tr>
<tr>
<td>FFR</td>
<td>Effective Federal Funds Rate, Percent, Annual.</td>
<td>Research Division</td>
</tr>
<tr>
<td>Deregulation</td>
<td>Dummy equals one if state deregulated any restrictions of banks interstate branching.</td>
<td>Rice and Strahan (2010)</td>
</tr>
</tbody>
</table>
A.4 Figures and Tables

Figure 1

(a) Debt to income

(b) Per capita debt

Source: Bureau of Economic Analysis (BEA).

Figure 2: Per capita debt by state

Source: New York FED Center for Microeconomic Data.
Figure 3: Debt to income by state

Notes: debt-to-income ratio in each state. Obtained by divided total debt balance per capita with per capita personal income in every state. Data from NY FED Center for Microeconomic Data and the BEA.

Figure 4: Percent increase in debt-to-income and per capita debt between 1999 to 2006

Notes: The figure presents a "heat map" of US states. The color index to the right of the map depicts the colors associated with the percent growth in debt-to-income and per capita total debt between 1999 to 2006 divided by state.
### Table 2: Descriptive Statistics

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<th>Mean</th>
<th>St. Dev.</th>
<th>Min</th>
<th>Max</th>
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*Notes:* Descriptive statistics for the main variables. 1994 - 2005. Full descriptions and sources of all variables are given in Appendix A.3
Table 3: Results for main estimation

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<td>0.30***</td>
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<td>(0.005)</td>
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<td>0.004***</td>
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<td></td>
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<td>(0.001)</td>
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<td>Liquidity(t-1 )</td>
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<td>0.02***</td>
<td>0.02***</td>
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<td>Capitalization(t-1 )</td>
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<tr>
<td>( \Delta \text{HPI} )</td>
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<td>( \Delta \text{MP} \times \text{Deregulation} )</td>
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<tr>
<td>( \Delta \text{MP} \times \text{Size}_{t-1} )</td>
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<td>( \Delta \text{MP} \times \text{Capitalization}_{t-1} )</td>
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<td>-0.04**</td>
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Time effect: No, No, No, Yes, Yes
State effect: No, No, Yes, No, Yes
Observations: 68,973, 68,973, 68,973, 68,973, 68,973
R²: 0.34, 0.34, 0.35, 0.34, 0.35
Adjusted R²: 0.34, 0.34, 0.35, 0.34, 0.35
Residual Std. Error: 0.11, 0.11, 0.11, 0.11, 0.11

Notes: The table reports the results of estimating Equation (1). Dependent variable is the loan growth rate. Monetary policy (\( \text{MP} \)) is measured using the effective federal funds rate. Deregulation is a dummy equal to 1 if a state lifts one or more branching restrictions. Robust standard errors, clustered at the bank level, are reported in parentheses. Full descriptions and sources of all variables are given in Appendix A.3.

*p<0.1; **p<0.05; ***p<0.01
Table 4: Calibration Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
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<td>β</td>
<td>Household discount factor</td>
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<tr>
<td>β_e</td>
<td>Entrepreneur discount factor</td>
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<tr>
<td>j</td>
<td>Weight of housing in the households’ utility</td>
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<tr>
<td>φ</td>
<td>Inverse of labor supply elasticity</td>
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<tr>
<td>α</td>
<td>Housing share in production</td>
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<td>θ</td>
<td>Calvo parameter</td>
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<td>ε</td>
<td>elasticity of substitution</td>
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<td>Standard deviation credit shock (in %)</td>
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<td>σ_R</td>
<td>Standard deviation monetary shock (in %)</td>
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Figure 5: Contractionary Monetary Shock - Baseline Model

Notes: Horizontal axis measures quarters after the shock. Vertical axis are deviation from steady state values (in %)
Figure 6: Positive Technology Shock - Baseline Model

Notes: Horizontal axis measures quarters after the shock. Vertical axis are deviation from steady state values (in %)

Figure 7: Expansionary Credit Shock - Baseline Model

Notes: Horizontal axis measures quarters after the shock. Vertical axis are deviation from steady state values (in %)
Figure 8: Positive Technology Shock - Comparing Policy Regimes

Notes: Horizontal axis measures quarters after the shock. Vertical axis are deviation from steady state values (in %)

Table 5: Volatility Of Key Variables

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<th>Imperfect competition</th>
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<td>b</td>
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<td>Technology shock</td>
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<tr>
<td>Benchmark</td>
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<td>2.930</td>
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<td>Macroprudential</td>
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<td>Macroprudential &amp; LATW</td>
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<td>2.440</td>
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</tbody>
</table>

Notes: Comparing output, Y, inflation, π, debt, b, and housing prices, q, volatilities under alternative policy rules and banks’ competition. Standard deviations are computed using simulated series and expressed as percent deviations from steady state.