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Desirable Banking Competition and Stability*

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Abstract

Every financial crisis raises questions about how the banking market structure affects the real economy. Although low bank concentration may lower markups and foster bank risk-taking, controlled banking concentration systems appear more resilient to financial shocks. We use a nonlinear dynamic stochastic general equilibrium model with financial frictions to compare the transmissions of shocks under different competition and concentration configurations. Oligopolistic competition and concentration amplify the effects of the shocks relative to monopolistic competition. The transmission mechanism works through the markups, which are amplified when banking concentration is increased. According to financial stability and social welfare objectives, the desirable banking market structure is determined. Depending on policymakers' preferences, the banking concentration of five to seven banks balances social welfare and bank stability objectives.

תחרות ויציבות בנקאית רצויות

יונתן בן שימול וקרולין בוזו

תקציר

מאז ומעולם משברים פיננסיים מעלים שאלות באשר לאופן בו המבנה של המערכת הבנקאית משליך על הפעילות הריאלית. על אף שריכוזיות נמוכה במערכת הבנקאית עשויה להפחית את המארק-אפ (מרווח מחירים) ולעודד נטילת סיכונים מצד הבנקים, נראה דווקא כי מערכות בנקאיות ריכוזיות, אך מפוקחות, עמידות יותר בפני זעזועים פיננסיים. במאמר זה, אנו משתמשים במודל ה-DSGE הלא לינארי, עם חיכוכים פיננסיים, על מנת לבחון את התמסורות מזעזועים תחת תצורות שונות של רמת תחרות והריכוזיות במערכת הבנקאית. אנו מוצאים כי מבנה אוליגופוליסטי של המערכת הבנקאית מעצים את השפעות הזעזועים בהשוואה למבנה מונופוליסטי. מנגנון התמסורת עובד דרך המארק-אפ שהופך למובהק יותר עם עלייה ברמת הריכוזיות. אנו מגדירים את המבנה המועדף שנמצא בהלימה עם יעדי היציבות הפיננסית והרווחה החברתית ; ומוצאים, כי בהתאם להעדפות של קובעי המדיניות, המערכת הבנקאית הכוללת בין חמישה עד שבעה בנקים עונה על האיזון הנדרש בין יעדי הרווחה החברתית לבין השמירה על היציבות של המערכת הבנקאית.

1 Introduction

Post the global financial crisis (GFC), banking competition became a key field of study; political and economic policies, banking unions, and especially regulations transformed the banking market. A desirable banking market structure emerged as the central focus point (Vives, 2016), which was not established theoretically based on a dynamic stochastic general equilibrium (DSGE) perspective that considers the combined effect of agents' welfare, financial stability, and macroeconomic dynamics.[1] This study aims to address this gap by identifying the desirable number of banks that would improve financial stability[2] and social welfare.

The relationship between bank competition and financial stability as well as welfare is complex owing to the intermediation role played by banks. First, whether or not bank competition improves welfare may vary with the market size, institutional environment, and ownership structure of banking systems (Berger and Mester, 1997). Second, literature provides two opposing views on the relationship between bank competition and financial stability (Allen and Gale, 2004a). On the one hand, banking market concentration is assumed to contribute to greater financial stability, making the economy less sensitive to financial shocks (Keeley, 1990; Allen and Gale, 2004b; Beck et al., 2006, 2013). This assumption aligns with the traditional *competition-fragility* view, which argues that higher competition leads to lower markups and encourages bank risk-taking. On the other hand, *competition stability* argues that banking market concentration makes the financial market more fragile and less likely to absorb financial shocks (Mishkin, 1999; Boyd and De Nicoló, 2005) and exposes the banking sector to more operational risk (Curti et al., 2022). Low bank concentration results in banks charging firms higher interest rates, resulting in riskier firm behavior. The expected rate of return on bank assets and the standard deviation of those returns will rise when bank concentration is related to bank market power.

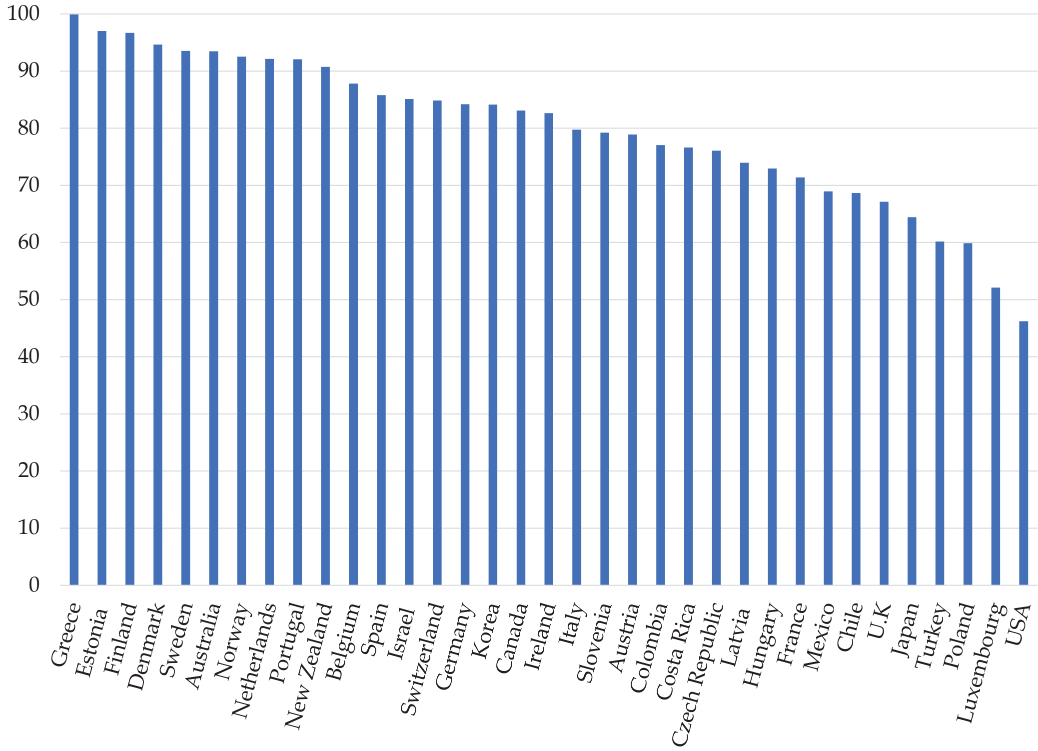
Most developed countries experienced a wave of banking market concentrations in the late 1990s. Banking market concentration can be assessed using

[1]Several studies have analyzed welfare and banking competition (Cuciniello and Signoretti, 2015; Lucchetta, 2017), financial stability and banking concentration (Boyd and De Nicoló, 2005; Corbae and Levine, 2022), and macroeconomic dynamics and banking competition (Boyd and De Nicoló, 2005). However, to the best of our knowledge, no structural welfare analysis has been conducted on the trade-off between financial stability, banking concentration, and competition in a fully microfounded macroeconomic DSGE model.

[2]Banking regulations, notably, capital requirements implemented under the Basel III accords, highlight the role of bank liquidity in the absorption of financial shocks by the banking sector. Thus, well-capitalized banks should guarantee financial stability.

various measures. For example, the concentration ratio can be used to measure the value of assets held by the five largest banks in each country as a share of the total value of commercial banks' assets. For instance, concentration ratio in the US banking market rose sharply from 30% in the early 2000s to approximately 45% in 2017 (see Section 2). However, the US concentration ratio is still below the OECD average (Fig. 1).

Figure 1: Banking Concentration in the OECD



Note: The y-axis represents the five largest banks' assets as a percentage of total commercial banking assets in 2017. Total assets include earning assets, cash and dues from banks, foreclosed real estate, fixed assets, goodwill, intangible assets, current tax assets, deferred tax, discontinued operations, and others. *Source*: 5-Bank Asset Concentration, Federal Reserve Bank of St. Louis.

The issue of bank competition has been receiving increased attention for the following reasons. First, in the aftermath of the GFC, regulated and concentrated banking markets appeared more resilient to crises. Australia and Canada are examples of countries where the regulation on bank competition may have preserved financial stability during and after the GFC (Brown et al., 2017; U-Din et al., 2022). Their regulation prohibits mergers between the largest banks and maintains an oligopolistic and highly concentrated banking market structure.[3] Policymakers have arbitrarily oriented their desirable bank concentration policy (number of banks) towards strong market power at four for Australia and five for Canada. Second, the banking competition issue is central to Europe, particularly because of the debate on whether cross-border banking consolidation is a vector of financial integration or a means of reducing excess capacity (Nouy, 2017).

To determine the most desirable and stable market structure, we examine and compare four banking market structures: perfect competition (PC), monopolistic competition (MC), Cournot competition (CC), and Bertrand competition (BC). The evaluation was conducted using a nonlinear DSGE framework by comparing the different measures of financial stability with those of welfare.

Our study is at the intersection of several strands of literature. Even when financial intermediaries are considered in the DSGE literature, these models disregard their role by assuming PC, despite empirical and theoretical evidence stating that banks compete imperfectly (Kiyotaki and Moore, 1997; Bernanke et al., 1999; Iacoviello, 2005). Using such a framework makes it impossible to accurately assess the effects of financial sector shocks on economic variables. While private banks have no market power and cannot influence interest rate settings in these models, they play a key role in business cycles and potentially have a significant impact on social welfare. Although banking literature has grown significantly since the GFC (Meh and Moran, 2010; Kollmann et al., 2011; Angeloni and Faia, 2013; Brunnermeier and Sannikov, 2014), the banking sector's critical characteristics have not been adequately investigated. Some models incorporate the financial sector as a technical feature (Iacoviello, 2015). Others are designed to consider financial shocks without considering the influence of bank market power (Kiley and Sim, 2017). By considering MC and introducing the idea that bank markups are determined by their market power, Gerali et al. (2010) make significant contributions to the literature. Market power has become an essential element in interest rate setting (Gerali et al., 2010; Darracq Pariès et al., 2011; Brzoza-Brzezina et al., 2013).

MC confers a specific market power to banks but still does not consider certain characteristics of the banking sector (e.g., the limited number of banks, strategic interactions, and barriers to entry). Consequently, oligopolistic competition should better capture most banking market characteristics. This study presents an oligopolistic framework that addresses some of these shortcomings and considers the number of banks as a determinant of markups, contributing to the literature on the relationship between bank competition and concentra-

[3] In these two countries, five banks hold more than 80% of the market shares of loans and deposits.

tion, financial stability, and welfare. For simplicity, our model focuses only on the banks controlling the largest portion of the banking market and assumes that bank size is homogeneous within this group. Moreover, our models assume that goods are not perfectly substitutable.[4] Further investigation of heterogeneous bank sizes and banks too big to fail can be explored through a more detailed model.

This study provides a quantitative analysis of the transmission of real and financial shocks under three market structures (i.e., MC, CC, and BC). Our first category of results provides a comparison of different banking market structures. We show that introducing the number of banks (N) as a determinant of markups modifies the dynamics of interest rate setting. We find that oligopolistic market structures amplify real and financial shocks more than under MC, with financial shocks having greater effects under BC than under CC. A complementary analysis for several values of N shows that a concentrated market amplifies shocks more than under MC. Our second category of results includes the determination of the desirable number of banks that will maximize financial stability and minimize welfare losses. In this context, we find that an increase in the number of banks in the market alters banks' markup, which, in turn, affects financial stability. This negative correlation is related to the *competition-fragility* view. However, we find a positive correlation of households and entrepreneurs' welfare with the number of banks. Therefore, an oligopolistic market structure with fewer banks is less desirable for agents than a competitive market structure with more banks. The trade-off between social welfare and financial stability allows us to unravel the debate on the desirable number of banks by proposing fewer banks, thereby maximizing this trade-off.

The remainder of this paper is organized as follows. Our models of imperfect competitions are presented in section 2. Section 3 presents the calibration used for empirical matching, as presented in Section 4. Simulation results are presented in section 5. Section 6 presents the trade-off between welfare and financial stability maximization. 7 interprets the results and provides some policy implications, and Section 8 concludes the study.

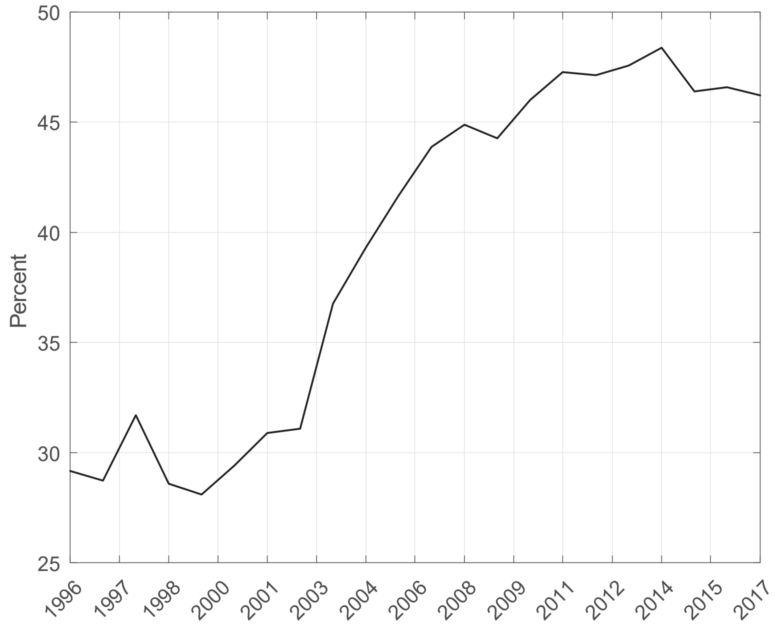
2 Imperfect Competition

Our models extend Gerali et al. (2010) by adding alternative banking competitions. Banks' market power was introduced through MC at the retail level in Gerali et al. (2010). While this implies that an infinite number of banks obtain

[4]Considering that homogeneous goods would involve bank interest rates equal to the marginal cost under BC, it leads us to the well known Bertrand paradox. In this case, the number of banks does not influence the model.

market power by differentiating their supply, this assumption seems unrealistic when we examine the evolution of the concentration ratio of the US banking market (Fig. 2). The US banking market is concentrated in five banks holding 50% of the market.[5]

Figure 2: Banking Concentration in the US



Note: The y-axis represents the five largest banks' assets as a percentage of the total commercial banking assets in the US. Total assets include earning assets, cash and due from banks, foreclosed real estate, fixed assets, goodwill, intangible assets, current tax assets, deferred tax, and discontinued operations and other assets. *Source*: 5-Bank Asset Concentration, Federal Reserve Bank of St. Louis.

Fig. 2 highlights two waves of concentration: the first in 2004 and the second in 2008. In 1997, the five largest banks held 30% of total bank assets, which increased to approximately 50% after the GFC[6].

Regulations in few countries favor an oligopolistic banking market framework, arguing that it would be a source of greater financially stability. From this perspective, we added two alternative competitions to the model of Gerali

[5]Considering the specificity of the banking system and data availability, we chose to analyze the US banking market in this study.

[6]This reality is not unique to the US market. Banking market concentration follows similar dynamics as most developed countries

et al. (2010): Cournot and Bertrand oligopolies. The oligopolistic framework allows us to introduce the desired number of banks in the loan interest rate setting behavior. The banking sector is structured as in Gerali et al. (2010) with a wholesale unit under PC, which manages the group's capital position and a segmented retail sector, which sets interest rates, according to their competition framework. MC allows banks to set interest rates above the fixed rate under PC because of their market power, obtained by differentiating the products (loans and deposits). The oligopolistic market structure differs from this framework as it assumes that the number of banks has an impact on interest rate setting behavior. We maintain the product differentiation hypothesis as it facilitates comparisons between models and avoids the *Bertrand paradox*, where markups are equivalent to those achieved under PC.

Consequently, introducing an oligopolistic market structure allows for a limited number of lending banks to compete on quantity (under CC) and price (under BC). Since policymakers can influence or control the number of banks (e.g., Australian Prudential Regulation Authority), it is assumed to be exogenous. We maintain the MC hypothesis for deposit banks as in Gerali et al. (2010), considering that an infinite number of differentiated agents supply deposits.[7]

The rest of our model is similar to that of Gerali et al. (2010) regarding the modeling hypotheses proposed; we present the details of the model in the Appendix. 8. Households supply labor, purchase goods for consumption and accumulate housing services. Entrepreneurs produce homogeneous intermediate goods using productive capital and labor supplied by households. Households and firms lend and borrow from the banking system. Patient households (Section A.1) discount the future less heavily than other agents, which guides their lending and borrowing behaviors. Consequently, they lend to the financial market, while impatient households (Section A.2) and entrepreneurs (Section A.3) borrow. Financial frictions are modeled using collateral constraints: agents willing to borrow in the market must hold a proportionate share of their loans in the form of collateral. We consider housing stock and capital stock as collateral for impatient households and entrepreneurs, respectively. We further introduce capital producers (Section A.5) as a modeling device to consider the varying capital prices, essential to determine the entrepreneurs' collateral value. We also consider the nominal rigidities essential for matching empirical data by adding retailers (Section A.4) who buy intermediate goods from entrepreneurs in a competitive market, differentiate between them at no cost, and resell them in a monopolistic market. Price rigidities are assumed to adjust *à la* Rotem-

[7]Few have quantified the ability of banks to set prices above the marginal costs of different banking products. According to Fernández de Guevara et al. (2005) using aggregate information on interest rates, the degree of competition varies across banking products (e.g., consumer loans, mortgage loans, and deposits).

berg (1982a,b) at the retail level. A monetary policy rule is assumed to close the model (section A.6).

In this section, we present the banking sector constructed as in Gerali et al. (2010) wherein each bank $j \in [0,1]$ in the model comprises two retail branches and one wholesale branch (Section 2.4). The retail loan branch offers differentiated loans to households and entrepreneurs, the deposit branch raises the differentiated deposits from households, and the wholesale unit manages the group's capital position. Different competitive market structures are assumed for retail loan branches, as they enjoy market power while conducting intermediation activities that depend on the banking market structure (MC, CC, and BC presented in Sections 2.4.1, 2.4.2, and 2.4.3, respectively).

2.1 Wholesale Branch

We assume that the bank's wholesale branch operates under PC and manages the bank's capital position. Banks must obey the balance sheet identity

$$K_{b,t} + D_t = B_t, \tag{1}$$

where the left-hand side corresponds to liabilities with $K_{b,t}$ (bank capital) and D_t (total deposits). The right-hand side corresponds to assets, with B_t being the sum of impatient $b_{i,t}$ and entrepreneur loans $b_{e,t}$. Bank capital follows the standard capital accumulation equation

$$\pi_t K_{b,t} = (1 - \delta_b) K_{b,t-1} + J_{b,t-1}, \tag{2}$$

where π_t is the level of inflation, $J_{b,t}$ is the aggregated bank net profit, and δ_b represents the resources expended in managing the bank capital.

The wholesale branch selects the quantity of loans and deposits that maximizes the discounted sum of cash flow

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^{P} \left[\begin{array}{c} (1 + R_{b,t}) B_t - B_{t+1}\pi_{t+1} + D_{t+1}\pi_{t+1} - (1 + R_{d,t}) D_t \\ + (K_{b,t+1}\pi_{t+1} - K_{b,t}) - \frac{\kappa_{kb}}{2} \left(\frac{K_b}{B_t} - v\right)^2 K_{b,t} \end{array} \right], \tag{3}$$

under the balance sheet constraint provided in Eq. 1. The bank pays a quadratic cost κ_{kb} when the capital-to-asset ratio deviates from the target value v. This assumption allows us to study the implications and costs of regulatory capital requirements. The wholesale loan $R_{b,t}$ and deposit rates $R_{d,t}$ are considered given.

By incorporating the balance sheet constraint in the wholesale branch optimization problem, we obtain the following simplified equations to maximize

$$R_{b,t} B_t - R_{d,t} D_t - \kappa_{kb} \left(\frac{K_{b,t}}{B_t} - v\right)^2 K_{b,t}. \tag{4}$$

The optimality condition is

$$R_{b,t} = R_{d,t} - \kappa_{kb} \left(\frac{K_{b,t}}{B_t} - v \right) \left(\frac{K_{b,t}}{B_t} \right)^2 . \tag{5}$$

Finally, to close the model, we assume that the wholesale deposit rate is equal to the policy rate $(R_{d,t} = R_t)$. This leads to the redefining of the optimality condition

$$R_{b,t} - R_t = -\kappa_{kb} \left(\frac{K_{b,t}}{B_t} - v \right) \left(\frac{K_{b,t}}{B_t} \right)^2 . \tag{6}$$

Aggregate profit of all the banks is

$$J_{b,t} = R_t^{b_i} b_{i,t} + R_t^{b_e} b_{e,t} - R_t^d d_t - adj_t, \tag{7}$$

where $R_t^{b_i}$ is the nominal interest rate on impatient households' loans, and $R_t^{b_e}$ is the nominal interest rate on entrepreneurs' loans. $b_{i,t}$ is the amount of loans granted to impatient households, $b_{e,t}$ is the amount of loans granted to entrepreneurs, R_t^d is the nominal interest rate on patient households' deposits, and d_t is the real amount of patient deposits. adj_t is composed of the quadratic adjustment cost of adjusting deposit rate (κ_d) and the quadratic cost observed when the capital-to-asset ratio deviates from the target value (κ_{kb}).

2.2 Deposit Demand

Banks raise deposits from an infinite number of differentiated depositors. The demand for deposits is aggregated through a CES aggregator. The demand for household deposits i is obtained by maximizing the revenue of total savings obtained from the continuum of bank j, such that

$$\int_0^1 R_t^d (j) \, d_t (i,j) \, dj, \tag{8}$$

subject to

$$\left[\int_0^1 d_t (i,j)^{\frac{\varsigma_{d,t}-1}{\varsigma_{d,t}}} dj \right]^{\frac{\varsigma_{d,t}}{\varsigma_{d,t}-1}} . \tag{9}$$

Combining first-order conditions, the aggregate household demand for deposits at bank j and $d_t(j)$ is given by

$$d_t (j) = \left(\frac{R_t^d (j)}{R_t^d} \right)^{-\varsigma_{d,t}} d_t, \tag{10}$$

where $R_t^d(j)$ is the bank's deposit rate, R_t^d is the economy-wide deposit rate, $d_t(j)$ is the demand for these bank deposits, and d_t is economy-wide demand for deposits. $\varsigma_{d,t}$ is the exogenous elasticity of deposit substitution, detailed in section 2.7.

2.3 Retail Deposit Branch

The interest rate set by banks on deposits represents their capacity to obtain deposits from households.

Each bank j chooses its deposit rate $R_t^d(j)$, which maximizes its profit

$$\mathbb{E}_t \sum_{t=0}^{\infty} \Lambda_{t,t+k}^b \left[\left(R_t - R_t^d(j) \right) d_t(j) \right], \tag{11}$$

where $\Lambda_{t,t+k}^b = \beta_b U'_{c,t+k}/U'_{c,t}$ is the stochastic discount factor of the bankers who are sole owners of banks, and R_t is the monetary policy rate.

The retail deposit bank is constrained by the deposit demand of patient households given by Eq. 10

After imposing a symmetric equilibrium, the first-order condition becomes

$$R_t^d = R_t \frac{\varsigma_{d,t}}{\varsigma_{d,t} - 1}. \tag{12}$$

2.4 Retail Loan Branch

The loan branch grants loans to impatient households and entrepreneurs.

The retail loan bank maximizes the profit function

$$\mathbb{E}_t \sum_{t=0}^{\infty} \Lambda_{t,t+k}^b \left[\sum_{k=e,i} R_t^{b_k}(j)\, b_{k,t}(j) - R_{b,t}(j) \left(\sum_{k=e,i} b_{k,t}(j) \right) \right], \tag{13}$$

where $b_{k,t}$ denotes the loans given to impatient households ($b_{i,t}$) and entrepreneurs ($b_{e,t}$), and $R_t^{b_k}$ is the rate on loans given to impatient households ($R_t^{b_i}$) and entrepreneurs ($R_t^{b_e}$) under loan demand, which is differentiated by the competition market structure.

Subsequently, we describe the loan demand function and maximization program for the loan branch in each competition scenario.

2.4.1 Monopolistic Competition

When the loan branch competes under MC, loan demand is aggregated using a CES aggregator (Gerali et al., 2010).

Loan demand from impatient households i and entrepreneurs is obtained by maximizing the total loan repayment because of the continuum of bank j

$$\int_0^1 R_t^{b_k}(j)\, b_{k,t}(i,j)\, dj, \tag{14}$$

subject to

$$\left[\int_0^1 b_{k,t}(i,j)^{\frac{\varsigma_{bk,t}-1}{\varsigma_{bk,t}}} dj\right]^{\frac{\varsigma_{bk,t}}{\varsigma_{bk,t}-1}}. \tag{15}$$

Combining the first-order conditions, aggregate households, and entrepreneurs' demand for loans at bank j, $b_{k,t}(j)$ is given by

$$b_{k,t}(j) = \left(\frac{R_t^{b_k}(j)}{R_t^{b_k}}\right)^{-\varsigma_{bk,t}} b_{k,t}, \tag{16}$$

where $R_t^{b_k}(j)$ is the bank's loan rate, $R_t^{b_k}$ the economy-wide loan rate, $b_{k,t}(j)$ is the demand for bank j loans, and $b_{k,t}$ is the economy-wide demand for deposits. $\varsigma_{b,k,t}$ denotes the exogenous elasticity of loan substitutability detailed in section 2.7.

In the following section, we detail the loan bank's maximization program. Each bank j chooses the rate $R_t^{b_k}(j)$ that maximizes the equation of the profits given by Eq. 13 under the CES demand function of loans, given by Eq. 16.

After establishing a symmetric equilibrium, the first-order condition associated with the bank problem for impatient households' and entrepreneurs' loan rate is

$$R_t^{b_k} = R_{b,t}\frac{\varsigma_{b_k,t}}{\varsigma_{b_k,t}-1}, \tag{17}$$

associated with the following loan markup equilibrium:

$$\mu_{b_k,t}^{MC} = \frac{\varsigma_{b_k,t}}{\varsigma_{b_k,t}-1}. \tag{18}$$

Finally, the markup depends on time-varying intertemporal elasticity of loan substitutability; notice that the markup decreases in the degree of loan substitutability.

2.4.2 Cournot Competition

We analyze competition in quantity (CC) with imperfectly substitutable loans, which requires an inverse demand function for loans. Starting from the aggregated demand function, we present the inverse demand function as in Colciago and Etro (2010).

We present the following function of expenses for each type of loan (denoted by index k), as follows:

$$\varrho_{bk,t} = \sum_{i=1}^{N} R_t^{b_k}(i)\, b_{k,t}(i) = R_t^{b_k} b_{k,t}. \tag{19}$$

From the standard function of demand, we have

$$b_{k,t}(j) = \left(\frac{R_t^{b_k}(j)}{R_t^{b_k}}\right)^{-\varsigma_{bk,t}} b_{k,t} = \frac{R_t^{b_k}(j)^{-\varsigma_{bk,t}}}{R_t^{b_k\,1-\varsigma_{bk,t}}} R_t^{b_k} b_{k,t}. \tag{20}$$

As we have $\varrho_{bk,t} = R_t^{b,k} b_{k,t}$,

$$b_{k,t}(j) = \frac{R_t^{b_k}(j)^{-\varsigma_{bk,t}}}{R_t^{b_k\,1-\varsigma_{bk,t}}} \varrho_{bk,t}. \tag{21}$$

After inversing the direct function of demand, we obtain the following: equation

$$R_t^{b_k}(j) = \frac{b_{k,t}(j)^{-\frac{1}{\varsigma_{bk,t}}}}{\varrho_{bk,t}^{-\frac{1}{\varsigma_{bk,t}}}} R_t^{b_k\,\frac{\varsigma_{bk,t}-1}{\varsigma_{bk,t}}}. \tag{22}$$

We plug Eq. 19 in Eq. 22 to obtain

$$R_t^{b_k}(j) = \frac{b_{k,t}(j)^{-\frac{1}{\varsigma_{bk,t}}}}{b_{k,t}^{\frac{\varsigma_{bk,t}-1}{\varsigma_{bk,t}}}} \varrho_{bk,t}. \tag{23}$$

We know that $b_{k,t} = \sum_{j=1}^{N} b_{k,t}(j)$. Hence, assuming that all banks take the total expenditure as given in each period, their perceived inverse demand function must be

$$R_t^{b_k}(j) = \frac{b_{k,t}(j)^{-\frac{1}{\varsigma_{bk,t}}}}{\sum_{i=1}^{N} b_{k,t}(i)^{\frac{\varsigma_{bk,t}-1}{\varsigma_{bk,t}}}} \varrho_{bk,t}. \tag{24}$$

Subsequently, we solve the maximization program for bankers. As banks compete on quantities, bank j chooses the loan amount $b_{k,t}$ that maximizes profits, which is given by Eq. 13, taking the production of all banks and the inverse function of demand as given (Eq. 24).

The first-order condition associated with the loan retail bank under CC is

$$R_{b,t} = \left(\frac{\varsigma_{b_{k,t}} - 1}{\varsigma_{b_{k,t}}}\right) \frac{b_{k,t}\left(j\right)^{\frac{-1}{\varsigma_{b_{k,t}}}} \varrho_{bk,t}}{\sum\limits_{i=1}^{N_t} b_{k,t}\left(i\right)^{\frac{\varsigma_{b_{k,t}}-1}{\varsigma_{b_{k,t}}}}} - \left(\frac{\varsigma_{b_{k,t}} - 1}{\varsigma_{b_{k,t}}}\right) \frac{b_{k,t}\left(j\right)^{\frac{\varsigma_{b_{k,t}}-2}{\varsigma_{b_{k,t}}}} \varrho_{bk,t}}{\left(\sum_{j=i}^{N_t} b_{k,t}\left(i\right)^{\frac{\varsigma_{b_{k,t}}-1}{\varsigma_{b_{k,t}}}}\right)^2}. \tag{25}$$

N banks compete on quantity for each period, choosing their individual supply $b_{k,t}\left(j\right)$ that maximizes profits by taking all other banks' supply as given. For all banks $j \in \{1, 2, ..., N\}$, Eq. 25 can be simplified by imposing a symmetric equilibrium.

This generates a symmetric individual loan supply

$$b_{k,t} = \frac{\left(\varsigma_{b_{k,t}} - 1\right)\left(N-1\right)\varrho_{bk,t}}{R_{b,t}\varsigma_{b_{k,t}}N^2}, \tag{26}$$

As $R_t^{b_k} = \varrho_{bk,t}/b_{k,t}$, we can write the expression for $R_t^{b_k}$, such that

$$R_t^{b_k} = R_{b,t}\frac{N}{\left(N-1\right)}\frac{\varsigma_{b_{k,t}}}{\varsigma_{b_{k,t}} - 1} \tag{27}$$

is associated with the loan equilibrium markup

$$\mu^C_{bk,t} = \frac{\varsigma_{b_{k,t}}N}{\left(\varsigma_{b_{k,t}} - 1\right)\left(N-1\right)}. \tag{28}$$

The markup under CC is higher than that under MC. This depends on the time-varying intertemporal elasticity of loan substitutability and the number of active banks in the market.

Analysis of the markup reveals that it is decreasing in the degree of substitutability between loans $\varsigma_{b_{k,t}}$ with an elasticity of $\xi^C_{k,t} = 1/(\varsigma_{b_{k,t}} - 1)$ and remains positive for any degree of substitutability, even for homogeneous loans ($\lim_{\varsigma_{b_{k,t}} \to +\infty} \mu_{bk,t} = N/\left(N-1\right)$). This allows us to consider the effects of strategic interactions in an otherwise standard setup with perfectly substitutable loans between banks.

The markup is decreasing and convex in the number of banks and it tends to $\lim_{N\rightarrow+\infty}\mu_{bk,t}\varsigma = \varsigma_{b_{k,t}}/\left(\varsigma_{b_{k,t}}-1\right) > 1$, for any degree of substitutability. Thus, when the number of banks tends to infinity, we find the case of MC. Its elasticity $\xi_N^C = 1/\left(1-N\right)$ decreases with the number of banks and is independent of the degree of substitutability between loans.

2.4.3 Bertrand Competition

We analyze competition in rates (BC) with imperfectly substitutable loans. Similar to firm competition in Faia (2012), we introduce BC for banks by considering a demand function for loans with strategic interactions.

From the standard function of demand, we have

$$b_{k,t}\left(j\right) = \left(\frac{R_t^{b_k}\left(j\right)}{R_t^{b_k}}\right)^{-\varsigma_{bk,t}} b_{k,t} = \frac{R_t^{b_k}\left(j\right)^{-\varsigma_{bk,t}}}{R_t^{b_k^{1-\varsigma_{bk,t}}}} R_t^{b_k} b_{k,t}. \tag{29}$$

As $\varrho_{bk,t} = R_t^{b_k} b_{k,t}$, we obtain

$$b_{k,t}\left(j\right) = \frac{R_t^{b_k}\left(j\right)^{-\varsigma_{bk,t}}}{R_t^{b_k^{1-\varsigma_{bk,t}}}} \varrho_{bk,t}. \tag{30}$$

We know that

$$R_t^{b_k} = \left[\sum_{i=1}^{N} R_t^{b_k}\left(i\right)^{-\left(\varsigma_{bk,t}-1\right)}\right]^{-\frac{1}{\varsigma_{bk,t}-1}}. \tag{31}$$

We replace 31 in 30 and obtain the direct demand function of deposit with strategic interactions

$$b_{k,t}\left(j\right) = \frac{R_t^{b_k}\left(j\right)^{-\varsigma_{bk,t}}}{\sum_{i=1}^{N} R_t^{b_k}\left(i\right)^{-\left(\varsigma_{bk,t}-1\right)}} \varrho_{bk,t}. \tag{32}$$

Similarly, the demand function with strategic interactions for each type of loan (denoted by index k) is:

$$b_{k,t}\left(j\right) = \frac{R_t^{b_k}\left(j\right)^{-\varsigma_{b_{k,t}}}}{\sum_{i=1}^{N} R_t^{b_k}\left(i\right)^{-\left(\varsigma_{b_{k,t}}-1\right)}} \varrho_{bk,t}. \tag{33}$$

Each bank j chooses rate $R_t^{b_k}\left(j\right)$ that maximizes profits given by Eq. 13 by assuming that the rate of other banks i and the demand function of loans with strategic interactions, as shown by Eq. 33, are given.

The first-order condition associated with the loan retail bank under BC is

$$\varrho_{bk,t}\left(\frac{\left(1-\varsigma_{b_{k,t}}\right)R_t^{b_k}(j)^{-\varsigma_{b_{k,t}}}}{\sum_{i=1}^{N}R_t^{b_k}(i)^{-\left(\varsigma_{b_{k,t}}-1\right)}}+\frac{\left(\varsigma_{b_{k,t}}-1\right)R_t^{b_k}(j)^{1-2\varsigma_{b_{k,t}}}}{\left[\sum_{i=1}^{N}R_t^{b_k}(i)^{-\left(\varsigma_{b_{k,t}}-1\right)}\right]^2}\right)$$

$$=R_{b,t}\varrho_{bk,t}\left(\frac{-\varsigma_{b_{k,t}}R_t^{b_k}(j)^{-\varsigma_{b_{k,t}}-1}}{\sum_{i=1}^{N}R_t^{b_k}(i)^{-\left(\varsigma_{b_{k,t}}-1\right)}}+\frac{\left(\varsigma_{b_{k,t}}-1\right)R_t^{b_k}(j)^{-2\varsigma_{b_{k,t}}}}{\left[\sum_{i=1}^{N}R_t^{b_k}(i)^{-\left(\varsigma_{b_{k,t}}-1\right)}\right]^2}\right). \tag{34}$$

In each period, N banks compete on prices and choose their individual loan rates $R_t^{b_k}(j)$ to maximize profits by taking all other banks' rates as given. For all banks $j=1,2,...,N$, Eq. 34 can be simplified by establishing a symmetric equilibrium. This generates a symmetric individual loan rate

$$R_t^{b_k}=R_{b,t}\frac{\varsigma_{b_{k,t}}(1-N)-1}{\left(1-\varsigma_{b_{k,t}}\right)(N-1)}, \tag{35}$$

which is associated with the following equilibrium markup

$$\mu_{d,t}^{B}=\frac{\varsigma_{b_{k,t}}(1-N)-1}{\left(1-\varsigma_{b_{k,t}}\right)(N-1)}. \tag{36}$$

The markup in price competition is smaller than that in quantity competition, and higher than the markup obtained in MC. Under CC, the markup decreases with the degree of substitutability between loans $\varsigma_{b_{k,t}}$ with elasticity

$$\xi_{k,t}^{B}=\frac{\varsigma_{b_{k,t}}N}{\left(\varsigma_{b_{k,t}}-1\right)\left(1-\varsigma_{b_{k,t}}+\varsigma_{b_{k,t}}N\right)}, \tag{37}$$

which is always higher than the elasticity obtained under CC. This indicates that higher substitutability reduces markup faster under rate competition. Moreover, the markup vanishes in the case of homogeneous loans under BC, such that $\lim_{\varsigma_{b_{k,t}}\to\infty}\mu_{d,t}=1$. This indicates that banks cannot generate higher markups under PC, when loans are perfectly substitutable). This is known as *Bertrand paradox*.

Finally, the markup also decreases with the number of banks, with an elasticity equal to

$$\xi_N^B = \frac{N}{(N-1)\left(1+\varsigma_{b_{k,t}}(N-1)\right)} \tag{38}$$

The elasticity under CC (ξ_N^C) is higher than that under BC (ξ_N^B), for any number of banks, implying that increasing the number of banks decreases markup faster under competition in quantity compared to that in rates. Moreover, the markup's elasticity to the number of banks under competition in rates decreases with the level of substitutability between loans, and tends to zero when the loans are homogenous.

The markups under CC and BC are endogenous, respond to the corresponding exogenous component ($\varsigma_{b_{k,t}}$), and depend on the number of banks (N), making the model steady-state dependent on N. See Appendix C for more details.

2.5 Financial Stability

Banking regulations, notably capital requirements implemented under Basel III, highlight the role of bank liquidity in the absorption of financial shocks by the banking sector. Thus, well-capitalized banks should ensure financial stability. Our model allowed us to simulate three indicators of bank liquidity: capital adequacy ratio (CAR), Z-score, and Solvency Ratio (SR). CAR measures the bank's capital, expressed as a percentage of loan exposure, such that

$$CAR_t = \frac{K_{b,t}}{B_t}, \tag{39}$$

where $K_{b,t}$ is the bank's capital and B_t is the aggregate loan. This ratio indicates whether banks have sufficient capital to handle certain losses before they become insolvent.

The z-score compares the buffer of a country's banking system (capitalization and returns) with the volatility of these returns, such that

$$ZS_t = \frac{ROA_t + \frac{K_{b,t}}{B_t}}{\sigma(ROA_t)}, \tag{40}$$

where $ROA_t = J_{b,t}/B_t$ is the return on assets with $J_{b,t}$ is the net bank profits and $\sigma(.)$ is the standard deviation operator. Aggregate z-score captures the probability of a default of a country's banking system.

SR corresponds to the bank's net profits expressed as a percentage of the bank's total liabilities, such that

$$SR_t = \frac{J_{b,t}}{K_{b,t} + D_t}. \tag{41}$$

As one of the key metrics for assessing a company's financial health, SR is used to gauge the likelihood of debt default.

2.6 Welfare Analysis

From a normative perspective, we seek the socially desirable number of banks for both households (patient and impatient) and entrepreneurs.

Following our nonlinear model, we compute the second-order approximation of the unconditional welfare for patient ($W_{p,t}$) and impatient ($W_{i,t}$) households and entrepreneurs ($W_{e,t}$), such that

$$W_{\varkappa,t} = \sum_{k=0}^{\infty} \beta_{\varkappa}^{k} U_{\varkappa,t+k}, \tag{42}$$

where $\varkappa = \{p, i, e\}$ determines the agent's type, $U_{\varkappa,t}$ denotes the utility function given by Eqs. 46, 51, and 58, and $\beta_{\varkappa}$ is the corresponding static discount factor.

Welfare in compensating variation terms (CEV) compares welfare in the benchmark model ($W^{*}_{\varkappa,t}$), with that in the corresponding model ($W_{\varkappa,t}$). This welfare is calculated as follows:

$$CEV_{\varkappa,t} = \exp\left[(1-\beta_{\varkappa})\left(W_{\varkappa,t} - W^{*}_{\varkappa,t}\right)\right] - 1, \tag{43}$$

where the benchmark model is without the banks' market power, for example, under PC.

We calculate total welfare in two steps. First, we aggregate the welfare of patient and impatient households and then add the welfare of entrepreneurs.

The social welfare function of households is defined as a weighted average between patient (λ) and impatient ($1-\lambda$) household CEV welfares:

$$CEV_{h,t} = \lambda CEV_{p,t} + (1-\lambda)\, CEV_{i,t}, \tag{44}$$

where $\lambda \in [0, 1]$ is the weight on savers' welfare. Following Mendicino et al. (2018), since there is no commonly accepted criteria for selecting weights assigned to each heterogeneous agent , we analyze the effects of different values of λ, including the proportion of patient households (μ). This approach is equivalent to exploring the Pareto frontier that can be reached by optimizing the number of banks.

Our welfare analysis seeks a socially optimal choice of the banking concentration system. We identify the number of banks that maximize the total social welfare in the economy, which is the average[8] of $CEV_{h,t}$ and $CEV_{e,t}$. As changing

[8]Alternative configurations and weightings are available upon request.

the number of banks increases the welfare of both classes of agents, maximizing the weighted sum of two groups of household welfare and entrepreneurs may not generate outcomes that worsen one of the groups' situations relative to the other.

2.7 Stochastic Structure

We assume that structural shocks to the banking sector follow a first-order autoregressive functional form, such that

$$X_t = (1 - \rho_X)\,\overline{X} + \rho_X X_{t-1} + \eta_t^X, \tag{45}$$

where $X_t \in \left\{\varsigma_{d,t}, \varsigma_{b_{k,t}}\right\}$, $\overline{X}$ is the steady-state value of X_t, and $\rho_X \in [0, 1[$ is the first-order autoregressive parameter of the shock X_t, and innovation η_t^X is a *i.i.d* normal error term with zero mean and standard deviation σ_X.

The stochastic structure of the other shocks and models are as follows: Appendix A.8.

3 Calibration

Our parameters are calibrated according to the literature and historical steady-state ratios in the US.[9] We calibrate $\beta_p = 0.994$ to obtain a deposit rate close to 2 percent. To ensure the binding of the collateral constraint in the steady-state[10] the discount factors of impatient households and entrepreneurs are calibrated to $\beta_i = 0.95$ and $\beta_e = 0.96$, respectively.

The relative weight of housing in the utility function j is calibrated to 0.2, which is close to the calculated ratio of US residential investment to GDP. The inverse of Frisch elasticity is calibrated to $\varphi = 1$, in line with the value of Galí (2008). Capital share in the production function α is 0.25, a value commonly used in the literature, the depreciation rate of capital δ_k is 0.03 as in Brzoza-Brzezina et al. (2013). The share of patient households μ is calibrated to 0.8 in

[9] We calibrate our model from quarterly US data. We made this choice owing to the data accessibility, quality, and sample length. This choice scarcely affects the calibration of our parameters. As demonstrated by Smets and Wouters (2005), the Eurozone's aggregated macroeconomic variable behavior was similar to that observed in the US, leading to a lack of significant difference in estimated parameters between these two monetary areas.

[10] In the steady-state, borrowing constraints bind if and only if the Lagrange multipliers (λ_i and λ_e) are greater than 0. As $\lambda_i = \frac{1}{c_i}\left(\beta_p - \beta_i\right)$ and $\lambda_e = \frac{1}{c_e}\left(\beta_p - \beta_e\right)$, which are greater than zero if and only if $\beta_p > \beta_i$ and $\beta_p > \beta_e$. Satisfying these constraints implies that borrowers always prefer borrowing rather than favor precautionary savings.

Table 1: Definition of estimated models' parameters.

Parameter	*Description*	*Calibration*
β_p	Patient households' static discount factor	0.994
β_i	Impatient households' static discount factor	0.95
β_e	Entrepreneurs' static discount factor	0.96
φ	Disutility of labor	1
j	Relative utility weight of housing	0.2
α	Capital share in the production function	0.25
μ	Labor income share of patient households	0.8
δ_k	Depreciation rate of physical capital	0.03
$\overline{\epsilon}$	Steady-state price markup	11
ι_p	Price stickiness index to past inflation	0.15
v	Bank capital regulation	0.08
$\overline{\varsigma_d}$	Steady-state elasticity of substitution of deposits	-1.02
$\overline{\varsigma_{bi}}$	Steady-state elasticity of substitution of impatient loans	2.95
$\overline{\varsigma_{be}}$	Steady-state elasticity of substitution of entrepreneur loans	2.6
$\overline{m_{i,t}}$	Steady-state LTV ratio of impatient households	0.7
$\overline{m_{e,t}}$	Steady-state LTV ratio of impatient entrepreneurs	0.25
ϕ_π	Weight on inflation in the monetary policy rule	2
ϕ_Y	Weight on output gap in the monetary policy rule	0.2
ρ_R	Interest rate smoothing	0.8
$\overline{\pi}$	Steady-state gross inflation rate	1

line with Iacoviello and Neri (2010). The steady-state price markup $\overline{\epsilon}$ is calibrated to 11, leading to a price markup of 1.1%, a value common in literature (Galí, 2008). The impatient households' LTV ratio, $\overline{m_{i,t}}$ is 0.7 in line with the US share of housing loans to GDP and Iacoviello (2005). Entrepreneur's LTV ratio, $\overline{m_{e,t}}$ is 0.25, reflecting the evidence that entrepreneurs cannot collateralize their loans as easily as impatient households.

For banking parameters, only a few studies estimate the value for the US. The elasticity of substitution for deposit. $\overline{\varsigma_d}$ is -1.02, a value in line with a Fed rate equal to 1.20%. The elasticity of substitution for impatient households $\overline{\varsigma_{bi}}$ and entrepreneurs $\overline{\varsigma_{be}}$ loans are calibrated to 2.95 and 2.6, respectively, which reflects the average monthly spread between the loan rate to impatient households and firms and the monetary policy rate [11]. According to the recent con-

[11] The calibration of the banking sector parameters involves calculating the difference between the average bank rate (household and corporate) and the monetary policy rate. This

dition of the balance sheets of US commercial banks, we calibrate bank capital regulation v to 0.08. Since banks are considered symmetric in our model, number of banks is a proxy for bank concentration. In what follows, we calibrate the number of banks to $N = 4$ for model validation and extend N to consider different scenarios for banking market concentration.

4 Moment Matching

Table 2 presents the simulated steady-state ratio to output averages from our models, calibrated according to Table 1. We compare these theoretical averages with the historical US data.[12] The simulations are at a first-order approximation.

Table 2 shows that our models replicate averages of most of the historical variables in the confidence interval. Our models match key moments presented in the literature and additional moments such as bank profits,impatient and entrepreneur loan rates, which our models correctly replicate. However, labor averages are not well replicated,owing to the lack of precision in the modeled labor market. For instance, we do not assume wage rigidities to simplify the model.

Table 3 presents the simulated standard deviations and correlations for each competitive market structure, from the simulation of our models calibrated according to Table 1.

Comparing the simulated moments from Table 3 with the historical US data we find that our models are also in line with historical dynamics, except for a few variables' moments that are not correctly replicated. This is because the models are built to describe general economic and financial dynamics and not tailored specifically to crises or volatile dynamics. Consequently, bank capital and profits, which were highly volatile during the GFC and significantly affected by several crises during the last 55 years, cannot be reflected by our moments.

difference reflects the banks' market power. Given our different structural models, the calibrated value under oligopoly should vary according to value of N. For simplicity, we keep this value constant. Analysis of the matching moments shows that the two oligopoly specifications continue to match historical values, leading us to consider this hypothesis as not too restrictive.

Although we are aware of the limitations induced by this assumption, our theoretical analysis will not suffer because our interest is in the change in dynamics observed in rate setting when markups consider different market structures.

[12]See Appendix D for more details on the data.

Table 2: Moment Matching - First Order

	Averages				Confidence	
	MC	CC	BC	Hist.	Min	Max
Inflation	1	1	1	0.76	0.68	0.84
Output	1	1	1	1	0.85	1.15
Nominal rate	1.2	1.2	1.2	1.23	0.65	1.81
Consumption	0.88	0.87	0.88	0.66	0.66	0.66
Investment	0.1	0.1	0.1	0.13	0.12	0.13
Capital	3.42	3.35	3.39	3.94	3.77	4.10
Wages	0.36	0.36	0.36	0.33	0.22	0.44
Labor	1.96	1.97	1.97	1.37	1.32	1.41
Loans	1.44	1.33	1.4	1.26	1.17	1.35
Imp. Loans/Loans	0.43	0.40	0.42	0.42	0.42	0.43
Ent. Loans/Loans	0.57	0.60	0.58	0.58	0.57	0.58
Bank capital	0.16	0.15	0.15	0.07	0.06	0.07
Bank profit	0.02	0.03	0.02	0	0.00	0.00
Ent. loan rate	1.94	2.59	2.19	2.13	1.66	2.59
Imp. loan rate	1.81	2.41	2.01	2	1.65	2.34

Note: Historical moments are computed with data from 1975 to 2020. The averages represent the corresponding variable's steady-state ratios to output. These results are obtained by assuming four banks. Assuming another number does not affect the results. A 5% confidence interval is used across our 180 observations for each time series, and assumes a Normal distribution.

5 Simulations

In this section, we examine the response of the economy to real and financial shocks under MC, BC, and CC. We assume the same degree of loan substitutability in each model. We set the number of banks to four to remain in tandem with the banking market structure of most industrialized countries.[13] Using this number allows the banking industry to be modeled as a concentrated market, without falling into MC. We then examine the transmission of financial shocks in oligopoly under different banking market concentration scenarios (i.e., different values of N).

The impulse response functions were obtained by solving the nonlinear model: computed with an analytical steady-state and solved at the second-order ap-

[13]Impulse response functions for highly concentrated markets with two banks to less concentrated markets (up to 20 banks), as well as for different competition market structures (MC, BC, CC, and PC) are available upon request.

Table 3: Moment Matching - Second Order

	Std. Deviations				Correlations			
	MC	CC	BC	Hist.	MC	CC	BC	Hist.
Inflation	0.6	0.6	0.6	0.54	0.71	0.7	0.7	0.16
Output	1.37	1.36	1.37	1.3	1	1	1	1
Nominal rate	0.4	0.4	0.41	0.99	-0.23	-0.24	-0.23	0.15
Consumption	1.11	1.12	1.12	1.08	0.94	0.94	0.94	0.86
Investment	4.05	4.12	4.1	4.5	0.23	0.24	0.24	0.81
Capital	1.71	1.76	1.75	3.66	0.35	0.36	0.36	0.9
Wages	1.85	1.85	1.86	0.75	0.97	0.97	0.97	0.02
Labor	1.51	1.47	1.5	1.24	0.9	0.89	0.9	0.89
Loans	2.11	2.27	2.28	1.92	0.45	0.42	0.4	0.56
Bank capital	2.07	2.44	2.25	9.93	-0.07	-0.05	-0.06	0.02
Bank profit	22.41	18.53	20.98	35.01	0.02	0.01	0.03	0.33
Ent. loan rate	0.41	0.48	0.44	0.76	-0.08	-0.11	-0.1	-0.01
Imp. loan rate	0.42	0.51	0.48	0.83	0	0	0.03	0.01

Note: Historical moments are computed with data from 1975 to 2020. Correlations represent the corresponding variable's correlation to output. These results are obtained by assuming four banks. Assuming another number of banks does not affect the general results.

proximation. Impulse response functions are reported as percentage deviations from each variable's steady-state.

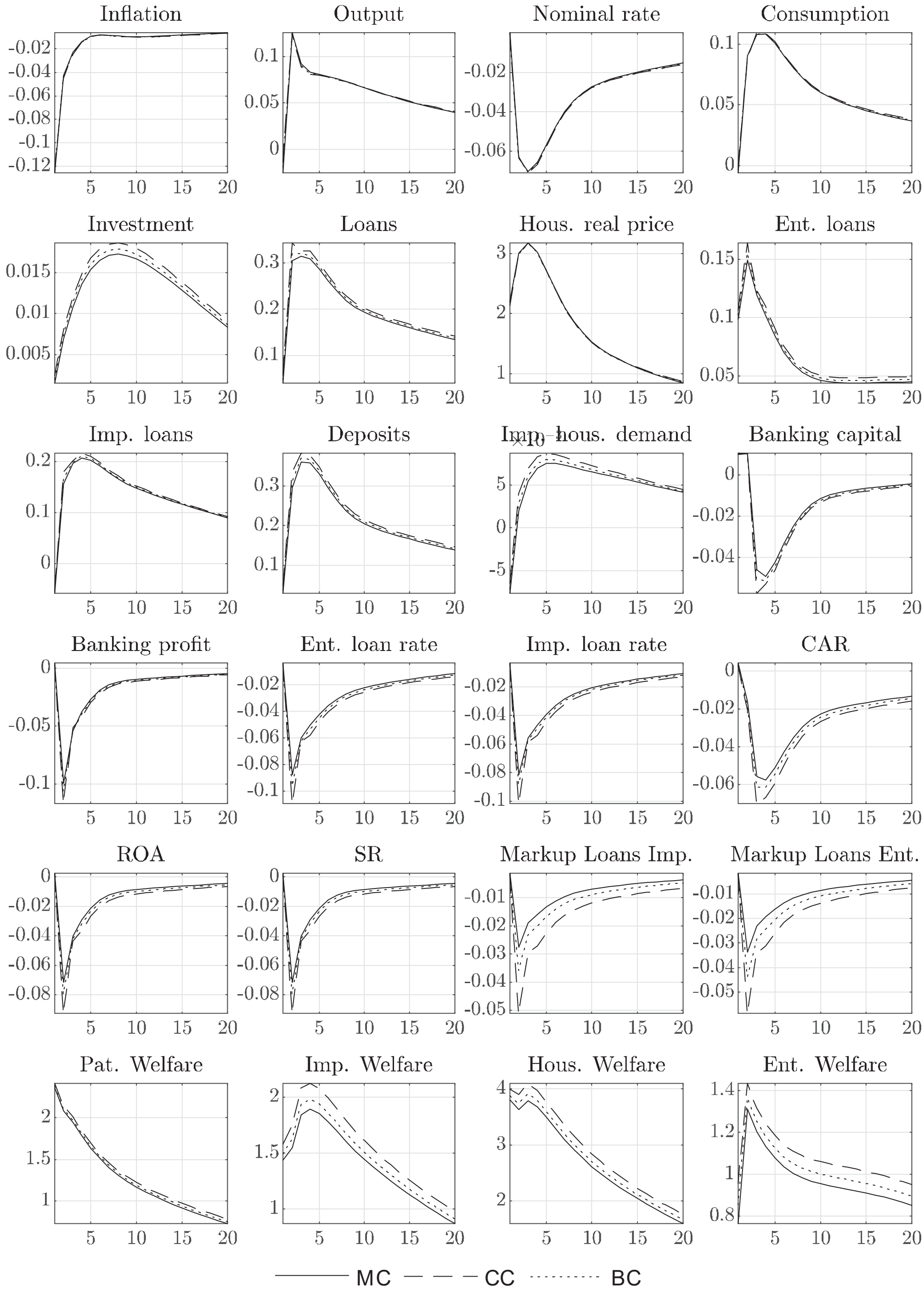
5.1 Technology and Competition

Fig. 3 compares impulse response functions for MC, price competition (BC), and competition in quantities (CC), following a technological shock.

Fig. 3 shows that the transmission mechanism of a technology shock in the banking sector is fairly standard across different competition market structures. After this shock, firms increase their production. Extra profits are generated by patient households that consume an increasing amount of leisure time. Impatient households also benefit from higher wages, allowing them to consume more. Additionally, the monetary authority lowers the policy rate as inflation declines. This is transmitted to retail rates, allowing entrepreneurs and households to obtain better loan terms. Loan amounts are higher, increasing the amount of investment and impatient households' housing demands.

In line with theoretical analysis, under imperfect competition, the rate set by banks is higher than the monetary policy rate. Banks benefit from market

Figure 3: Response to a 1% technology shock (in %)



power, allowing them to fix the rate above what would prevail under PC (Gerali et al., 2010).

Among imperfect competition scenarios, we observe that the bank generates lower markups in an oligopolistic market structure than MC. Additionally, markups further deteriorate when competition is in quantity rather than in rates, such that $\mu^{MC}_{b_k,t} < \mu^{B}_{bk,t} < \mu^{C}_{bk,t}$. This is in line with the calculation of markup elasticity to number of banks. No matter how concentrated the banking sector is, elasticity under CC is greater than that under BC. Thus, the banking market structure modifies technology shock transmission through the markup channel.

This translates to other macroeconomic variables. Bank interest rates fall more in oligopolies, leading to a greater increase in loans and even more so when banks compete in quantities. Investment and housing responses follow the same pattern. Bank liquidity is negatively affected by a decrease in markups, especially when banks are in oligopoly. Interestingly, unconditional household and entrepreneurial welfare[14] increases more under CC than under BC or MC.

5.2 Monetary Policy and Competition

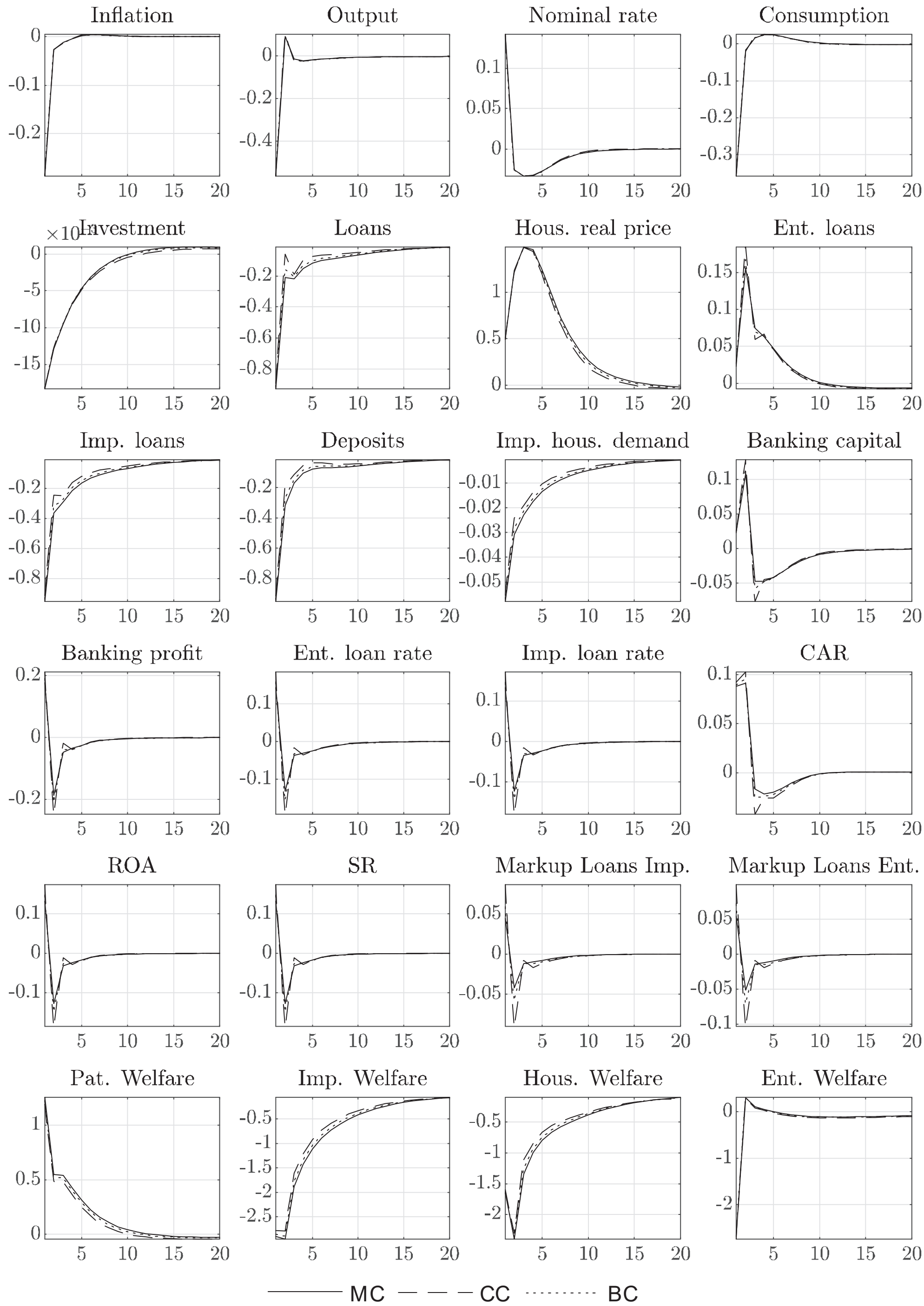
The transmission mechanism of a monetary policy shock to the remainder of the economy is standard. As in Gerali et al. (2010), monetary policy is transmitted through the real rate, financial accelerator, and nominal debt effects (Fig. 4).

Increase in monetary policy rate leads to an increase in real rates, as prices in the economy are considered sticky. Facing higher rates, households decide to postpone consumption. Moreover, the nominal debt effect works through the decrease in prices. This leads to a rise in the real cost of current debt and pushes borrowers to deleverage, cut loan demand, and thus, investment and impatient households' housing demand. Finally, financial accelerator effect works through the collateral value. The rate increase reduces collateral value, forcing banks to reduce granted loans, which also reduces investment and impatient households' housing demand.

The magnitude of these changes depends on the competition market structure. A monetary policy shock affects interest rate setting dynamics of retail loan banks. As the policy rate positively affects the marginal cost of producing loans, an increase in policy rate translates to an increase in marginal cost. The marginal cost of producing loans is positively related to each equation of interest rate setting dynamics (Eq. 17, Eq. 27 and Eq. 35). As banks' market share (ϵ^{bk}) is considered given, oligopolistic banks choose a higher interest rate

[14] Welfare presented in Section 5 (Figs. 3 to 10) is the unconditional welfare, $W_{\varkappa,t}$ presented in Eq. 42. Welfare analysis in compensating variation terms (Eq. 44) is presented in Section 6.

Figure 4: Response to a 1% monetary policy shock (in %)



than MC for generating higher markups.[15] That is, for N and ϵ^{bk}, a change in R leads to a change in R^{b_k}, such that $R^{b_k}_{mc} < R^{b_k}_{bc} < R^{b_k}_{cc}$. We finally obtain the same structure for loan responses.

5.3 Loan Substitutability and Competition

We analyze shocks to bank markups. Markups depend on the number of banks in the economy (N) and the elasticity of loan substitutability. Here, we only focus on loan substitutability, and the number of banks remains fixed. Among financial shocks, we investigate a shock to the degree of loan substitutability for impatient households (ς_{bi}) and entrepreneurs (ς_{be}) for a fixed number of banks.[16]

Figs. 5 and 6 present the impulse response functions of variables following a financial shock more precisely, a shock on loan substitutability in different banking sector competition market structures.

A shock to the degree of loan substitutability leads to an increase in markups, which is generally related to credit crunch scenarios. Literature shows that a positive shock to the loan markup leads to an increase in related loan rate, which involves a decrease in loan amounts. We analyze a shock on impatient households' and entrepreneurs' loan rates.

A loan markup shock for impatient households (Fig. 5) increases the loan rate, leading to a decrease in impatient loans and hence, a decrease in housing demand. Loan markup shock for entrepreneurs (Fig. 6) increases entrepreneurs' loan rate, involving a decrease in entrepreneurs' loans and thus lowers investment. Fall in investment corresponds to a fall in aggregate demand, leading to a fall in output.

The magnitude of housing demand and investment decline depends on the banking market structure. These shocks affect the interest rate setting dynamics through a change in bank markup.

Markups in oligopoly are more sensitive to the degree of loan substitutability than under MC. Moreover, the elasticity of markup to loan substitutability

[15] We should be aware that number of banks was fixed at 4 in our analysis. The higher the number of banks in a market, the closer the oligopolistic competition is to the MC case, where banks have negligible impact on each other.

[16] Impulse response functions for highly concentrated markets with three banks to less concentrated markets, with five and ten banks are available upon request. According to the markup equations (Eqs. 28 and 36), bank markups are affected by the number of banks operating in the market. The fewer the banks, the more markups are affected. Responses of the macroeconomic variables follow the effects on markups; increase in loans and investments is greater when the market is concentrated and the response of financial stability indicators deteriorates even further owing to low number of banks.

Figure 5: Response to a 1% impatient households' loans markup shock (in %)

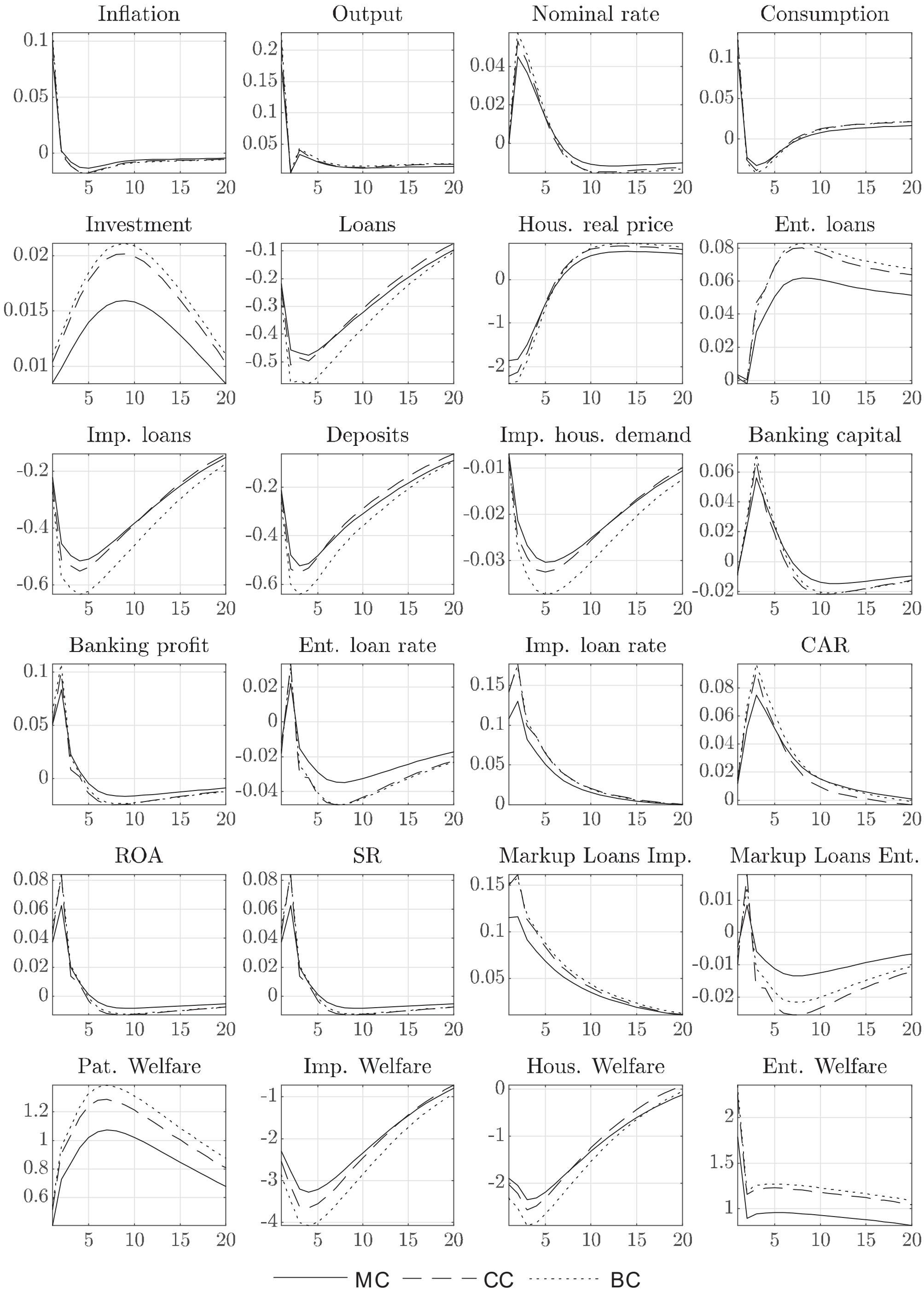
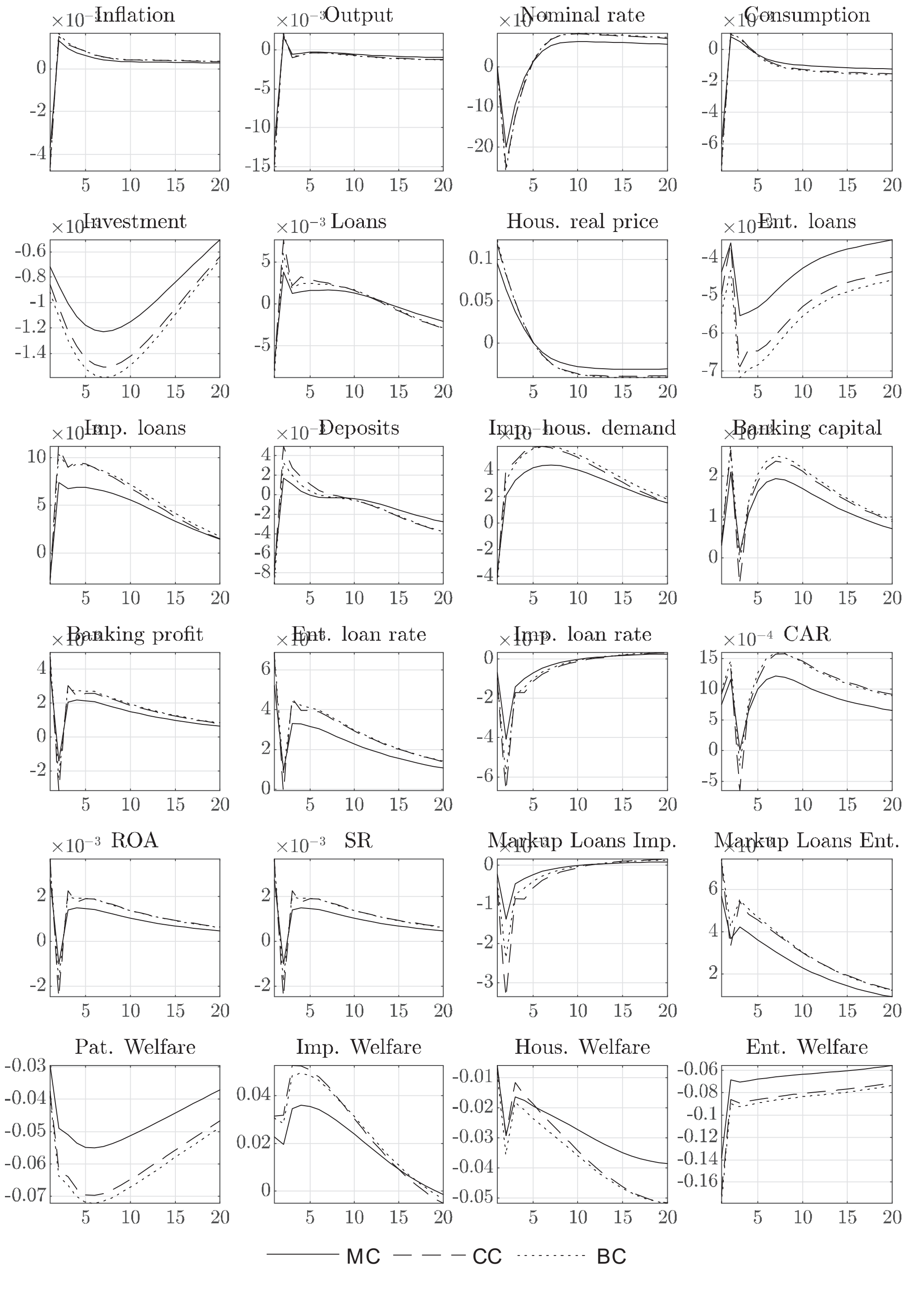


Figure 6: Response to a 1% entrepreneurs' loans markup shock (in %)



level is higher in BC than in CC, such that increase in the degree of substitutability causes Bertrand's markups to tend to those under PC.[17]

Following the shocks, welfare level increased, and differences among competitions followed the same pattern as markups.

5.4 Loan Substitutability and Concentration

Sections 5.1 to 5.3 showed that the competition market structure plays a role in transmitting shocks. Here, we examine the number of banks (concentration) influencing the transmission of financial shocks to the economy following a shock to the degree of loan substitutability for impatient households and entrepreneurs.

Fig. 7 and 8 present the responses of the economy following an impatient household's loans markup shock under CC and BC at different concentration levels. Banks may set higher rates in a more concentrated banking market, increasing their markups but deteriorating housing demand in low- compared to highly- concentrated markets. In both competitive market structures (CC and BC), impatient household loan markup shock under low concentration decreases more impatient loans than highly concentrated banking markets. In turn, this results in a lower-impatient household's unconditional welfare under less concentrated banking markets versus more concentrated ones.

A comparison of Figs. 7 and Fig. 8 shows how competition and concentration influence financial shock transmission. Under BC, increasing concentration caused a lesser decrease in loans than under CC. Concentration seems to affect the economy less for most variables following impatient households' loan markup shock under CC than under BC.

Fig. 9 and 10 present the economy's responses following an entrepreneur's loan markup shock for BC and CC at different concentrations. An entrepreneur loan markup shock lowers investment in low-concentration markets more than in high concentration ones. The decrease in investment corresponds to a decrease in aggregate demand, leading to a decrease in output and a decrease in the unconditional welfare of entrepreneurs and households, which is higher under low concentrations than under more concentrated banking markets. The effect of competition market structure on concentration is less important, following an entrepreneurs' loan markup shock rather than following an impatient households' loan markup shock.

[17] Markups are assumed fixed for the monetary policy shock (Fig. 4). Financial shocks influence markups, which influence banks differently. On the one hand, they strive to preserve markups. On the other hand, to increase them.

Figure 7: Response to a 1% impatient households' loan markup shock (in %) under BC

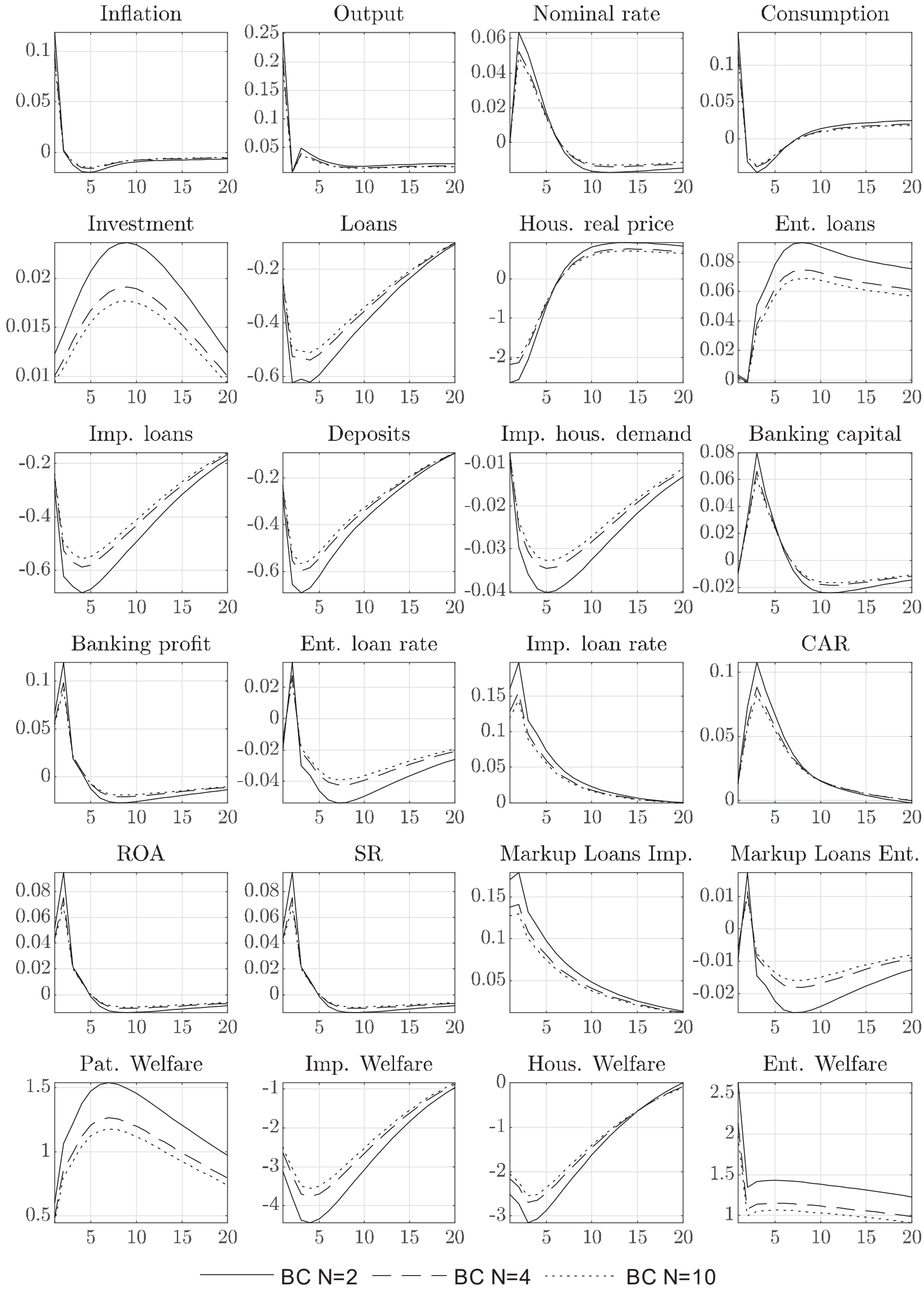


Figure 8: Response to a 1% impatient households' loan markup shock (in %) under CC

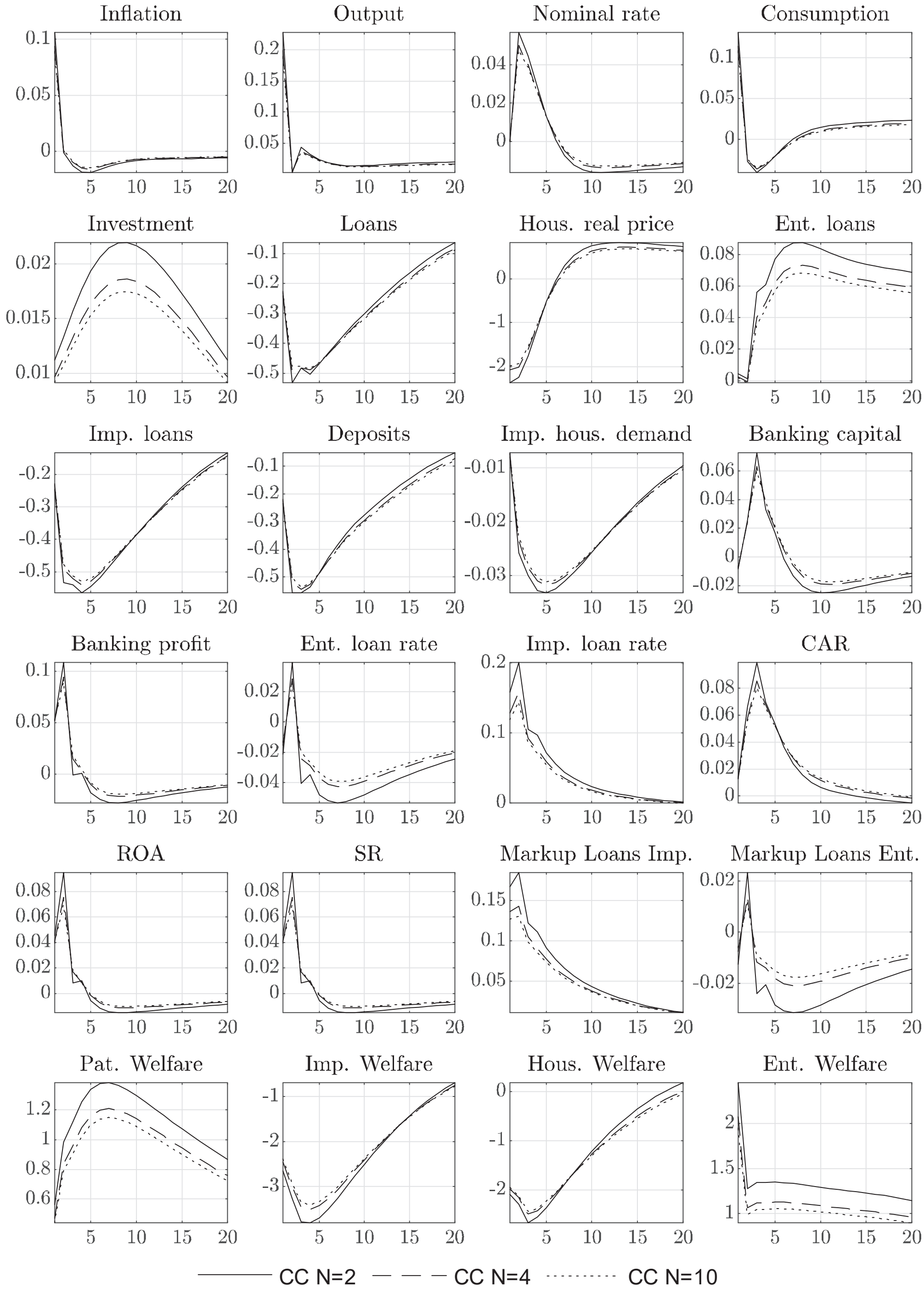


Figure 9: Response to a 1% entrepreneur loan markup shock (in %) under BC

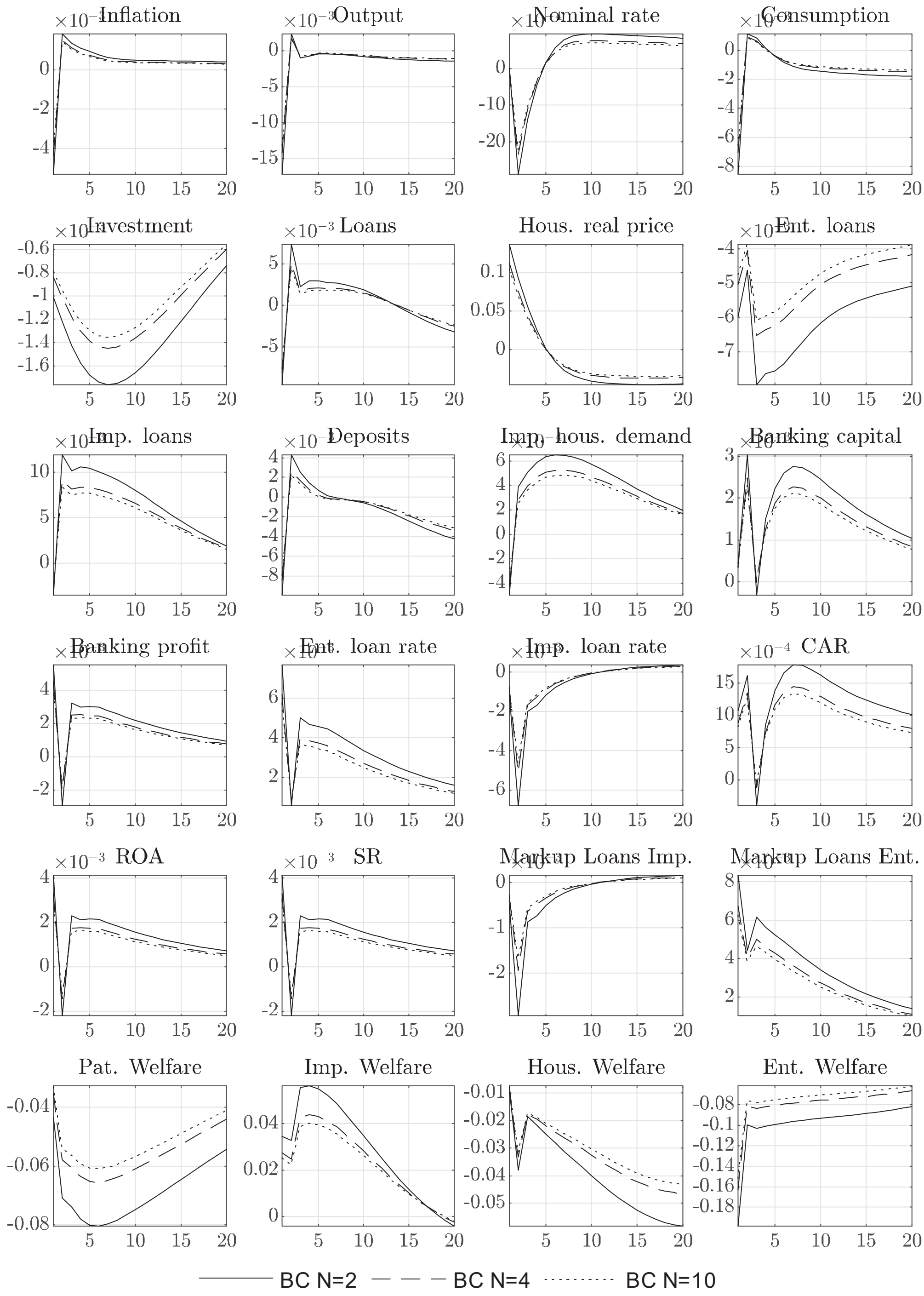
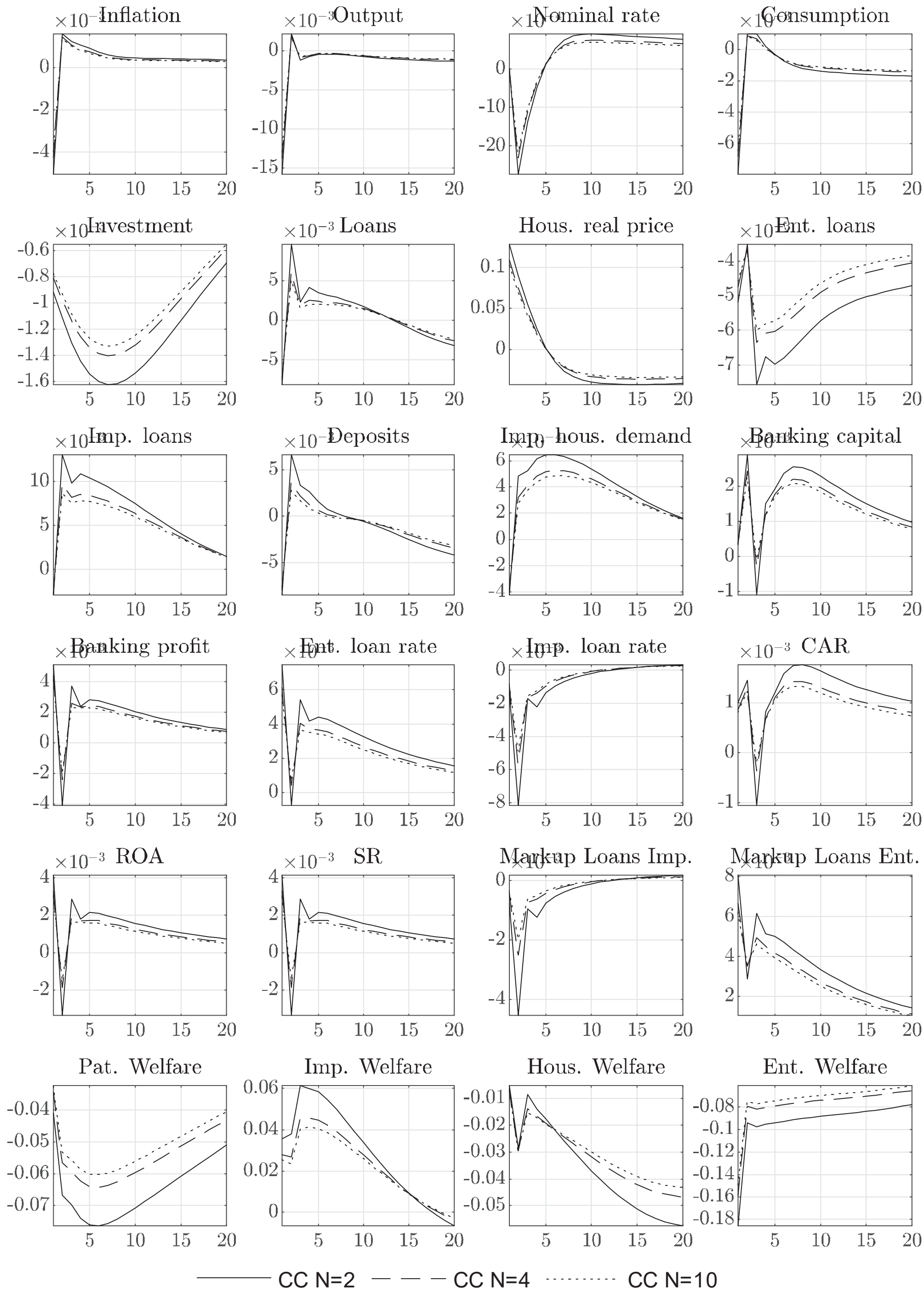


Figure 10: Response to a 1% entrepreneur loan markup shock (in %) under CC



6 Financial Stability and Welfare

We assess the number of banks that maximizes the households' unconditional welfare CEV and financial stability under imperfect competition. We obtained welfare simulation results by solving the nonlinear model and analytical steady-state in the second-order approximation. Since our theoretical model does not incorporate financial stability structurally, we present the following graph explanation of the welfare-financial stability trade-off.

Regarding welfare (see Fig. 11), PC is considered the benchmark model. This assumption is based on the fact that banks have no market power under PC, hence, markups are zero (i.e., preferred model by agents in terms of welfare). Since PC assumptions are difficult to observe in practice, we rely on this model only as a reference point for welfare analysis. Thus, we determine compensation variation welfare, which is equivalent to the consumption equivalent welfare measure that measures how many households can give up in terms of consumption in each period, to remain in an alternative state in the economy. Alternative states are characterized by imperfect competition in banking.

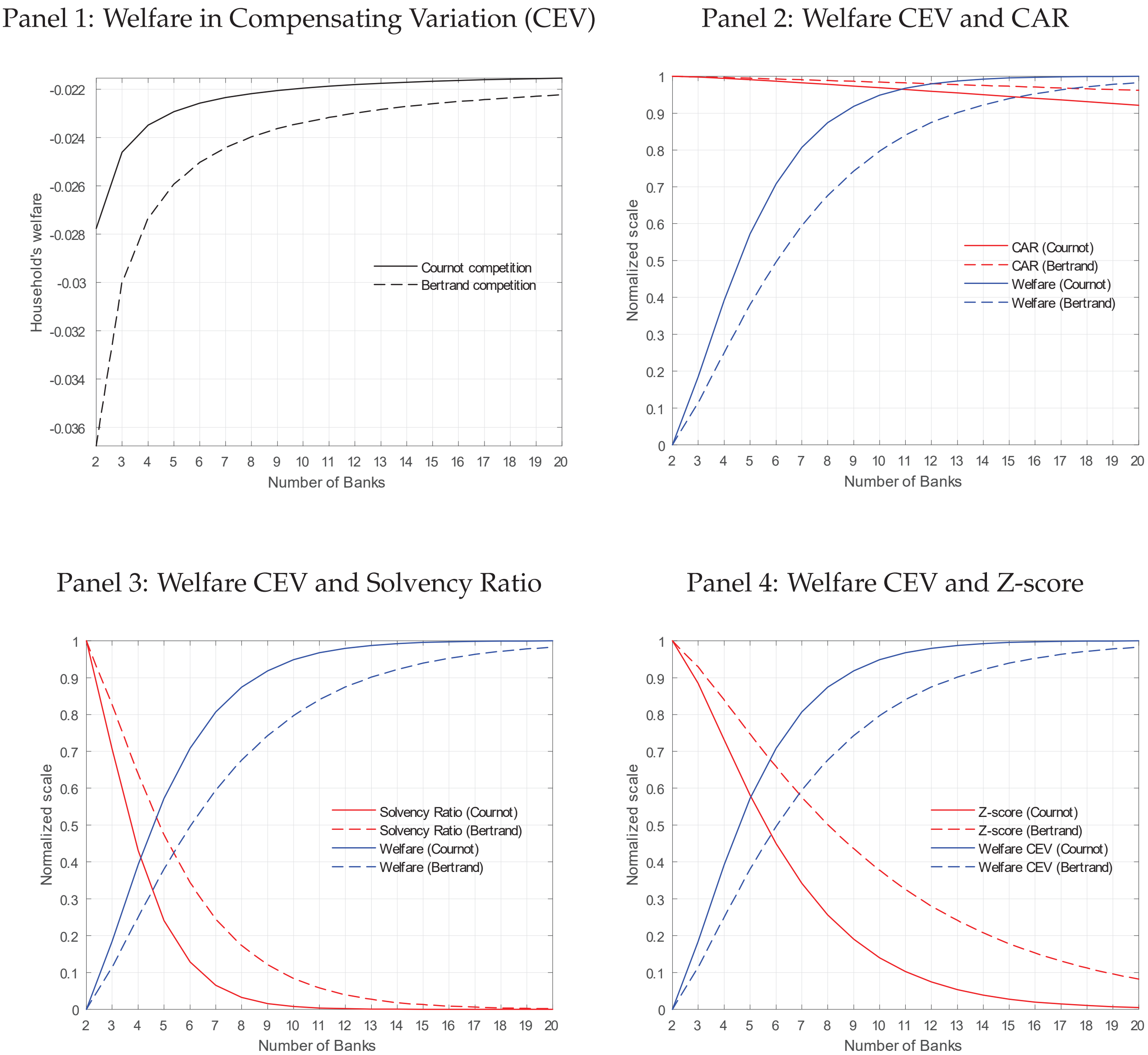
The results presented in Fig. 11 demonstrate that the oligopolistic market structure worsens agents' welfare compared to PC market structure. Additionally, we found that CC is always preferred to BC, regardless of the number of banks in the market: households give up 2.5% of their consumption to remain in CC, against 3% to remain in BC when there are four banks in the market. The number of banks also plays a key role in household welfare. Decreased banking concentration reduces household welfare loss.

These results relate to the effects of concentration on bank markups. The more consolidated the banking market, the more banks can set markups at a high level. Hence, consumer surplus and welfare deteriorate. In each competition market structure, the welfare curve increases with an increase in the number of banks, where the highest welfare levels correspond to an infinite number of banks.

We also assess the effect of banking concentration on financial stability using different banking stability ratios as presented in Section 2.5 (CAR, ZS and LDR). In Fig. 11, we observe that for each financial stability ratio, banking market concentration leads to improved financial stability. Those results align with the *competition-fragility* view, which argues that more market competition erodes market power, decreases markups, and results in a reduced franchise value that encourages bank risk taking.

The originality of our results lies in the comparison of welfare and financial stability ratios. The point of intersection between social welfare and financial stability curves represents a desirable number of banks that minimize welfare losses and maximize financial stability. This result assumes a policymaker who

Figure 11: Welfare and Financial Stability.



Note: the plain lines stand for CC and dashed lines for BC, blue lines for welfare CEV, and red for the corresponding financial stability indicator. Welfare and financial stability results from panels 2 to 4 are normalized to obtain values between 0 for the minimum welfare or financial stability ratio and 1 for the maximum. These results only consider household welfare.[18]

is indifferent between maximization of social welfare and financial stability.

Table 4 summarizes the results.

Table 4: Desirable Banking Concentration

	CAR		*SR*		*Z-score*		*Average*	
	BC	CC	BC	CC	BC	CC	BC	CC
Households ($CEV_{h,t}$)	11	8-9	5-6	4-5	7	5	8	6
Entrepreneurs ($CEV_{e,t}$)	9	7	5	4	5-6	4-5	6-7	5
Total (CEV_t)	10	7-8	5-6	4-5	6-7	4-5	**7**	**5-6**

Note: The numbers define the desirable number or interval number of banks in the economy. We assume that number of households is the same as number of entrepreneurs, and patient and impatient households are equally distributed. The policy maker assumes that welfare and financial stability are equally weighted. Results for different weighting or distribution assumptions are available upon request.

Based on these financial stability indicators, our results suggest that the desired number of banks is, on an average, between five and seven. For instance, intersection between the household welfare CEV and CAR ratio under CC is between eight and nine banks, and eleven under BC (Table 4). For solvency ratio (SR), the desirable number of banks is between four and five under CC and between five and six under BC, as far as household compensating variation welfare is concerned. Finally, the desirable number of banks is determined by the intersection of welfare CEV and Z-score is five and seven under CC and BC, respectively.

Overall, our model suggests that a banking market under CC should have between five and six banks, and seven under BC, on an average. Results in favor of a concentrated market are robust, regardless of the measure of financial stability.

Table 5 lists the desirable number of banks, assuming that the policymaker prefers increasing welfare over financial stability (60%-40%).

As expected from Fig. 11, a policymaker more concerned about maximizing household welfare over financial stability should increase the number of banks in an economy. In most cases, comparing Tables 4 and 5 yielded sharp differences.

Fernández de Guevara and Maudos (2007) showed empirically that the welfare gains of reducing market power in the banking sector outweigh the financial stability costs of doing so. Theoretically, our results show that decreasing market power results in greater welfare gains than a reduction in bank profitability, indicating how policy measures are important in removing entry bar-

Table 5: Desirable Banking Concentration - Policymaker Preferences

	CAR		*SR*		*Z-score*		*Average*	
	BC	CC	BC	CC	BC	CC	BC	CC
Households ($CEV_{h,t}$)	18	12	15	14	20	20	17-18	15-16
Entrepreneurs ($CEV_{e,t}$)	14	10	10	7	20	20	14-15	12-13
Total (CEV_t)	16	11	13	11	20	20	**16**	**14**

Note: The numbers define the desirable number or interval number of banks in the economy. We assume that the number of households is identical to that of entrepreneurs, and there is an equal distribution among patient and impatient households. The policymaker assumes here that welfare is more important than financial stability and assigns 60% and 40%, respectively. Results for different weighting or distribution assumptions are available upon request.

riers.

7 Interpretation and Policy Implications

Our simulations show that banks' interest rate setting behavior depends on banking sector concentration. A model that does not consider banking sector concentration could underestimate the effects of real and financial shocks.[19] Indeed, the number of banks as a determinant of markups amplifies the response mechanism of variables to shocks.

This dynamic analysis has limitations because the situation of banks prior to shocks (initial state) is unknown. Banking concentration could be linked to a better initial banking sector situation, which reduces the probability of financial crises (Jeasakul et al., 2014).

Strategic interactions among banks are beneficial to financial stability and detrimental to social welfare. When the behavior of other banks' drives banking decisions, the number of loans granted under CC is reduced, and interest rate levels under BC increase. Therefore, an adverse financial shock is mitigated under oligopoly, safeguarding financial stability.

Our second analysis evaluates concentration effects on welfare and financial stability. It shows that a concentrated banking sector worsens household welfare and firms compared to a less-concentrated sector because banks can set higher rates to generate higher markups.

Higher concentration in the banking system improves financial stability as

[19]Financial shocks discussed are credit crunch scenarios. The model does not consider the risk of bank default.

bank markups increase. In contrast, a high-banking market concentration should improve financial stability ratios, making banks more resilient to financial crises as it allows banks to increase their markup, which deteriorates consumer surplus and, finally, social welfare.[20]

Reconciling these two effects allows us to establish a desirable banking sector concentration, reducing welfare losses and augmenting financial stability indicators. This desired concentration ranges from five to seven banks, on average, depending on the market structure and central banker's preferences.

Maximum welfare and financial stability for a specific banking concentration depends on policymaker preferences. Policymaking preferences may change our baseline policy recommendation, assuming undifferentiated preferences between social welfare and financial stability.[21] These results relate to the debate on banking competition. Indeed, while some favor banking sector competition, arguing for greater credit availability, policymakers must consider potential negative implications on financial stability.

Our simulations show that larger banks capture a sizable market share in our model, amplifying financial shocks. Models considering monopolistic bank competition underestimate the effects of shocks as they cannot consider banking markets with large banks (low N).

Our study answers two questions raised in the aftermath of the GFC. First, bank consolidation reduces banks' risk-taking behavior (static analysis). Second, because the concentrated banking market involves large banking institutions, the bank size effect amplifies shocks. Our dynamic analysis shows that a banking market with sizable banks is more fragile than that with many small banks. Banks may also behave more riskily because of moral hazard, reinforcing bank fragilities and further amplifying shocks.

Finally, our macroeconomic model and results do not include small banks or financial institutions that can be considered regular banks, which make up less than one-fifth of the banking sector. Concomitantly, owing to a more heterogeneous banking sector, welfare curves should move to the right to compensate for the presence of "too big to fail" banks. The heterogeneous banking sector should, however, push financial stability ratios to the left in order to emphasize the riskier banking market structure compared to our homogeneous sector. Our theoretical findings are likely to remain unchanged owing to these two dynamics.

Although we consider monetary policy shocks, optimal monetary policy,

[20]Our model did not measure probability of bank default. However, we consider it to be positively correlated with the financial stability ratios, particularly the z-score (Hafeez et al., 2022).

[21]Financial stability may be preferred by some policymakers at the cost of social welfare, while others may prefer to preserve social welfare at the cost of financial stability.

monetary policy frameworks and rules are out of the scope of the present article. Our theoretical model does not also consider shadow banks, small banks with limited services, and the frequency policymakers change N. The last example is the decision to open the banking market to a new entrant in Israel (2019).

8 Conclusion

This study investigates how bank competition affects financial stability and social welfare. To assess this effect, we built and used a nonlinear DSGE model with financial frictions and assumed alternative imperfect competitions in the banking sector. Our findings show that the policymaker's choice to reduce competition in the banking sector should result in a trade-off between reduced welfare and increased financial stability.

Our study provided two sets of results. The first set of results show that banks' interest rate setting behavior depends on banking sector concentration. A model that does not consider banking sector concentration could underestimate the effects of real and financial shocks. Indeed, the number of banks as a determinant of markups amplifies the response mechanism of variables to shocks.

The second set established a relationship between competition and welfare. We found that all imperfect competition negatively affects welfare as compared to the benchmark case of PC. Furthermore, we found that in MC, an infinite number of banks are preferred over a limited number of banks, as in the case of oligopolistic competition. Finally, CC is always preferred to BC regardless of the number of banks.

We analyze the effect of competition on financial stability, using three measures. Our results favor the *competition-fragility*, arguing that a more competitive market reduces bank markups and risk-taking, which fosters financial stability. Specifically, we find that our financial stability measures are lower when the market is less concentrated. These results are validated by the contribution of financial shocks in the variance decompositions, amplified in a concentrated market characterized by an oligopolistic structure (Appendix G). Finally, the most desirable banking sector concentration system mitigates welfare losses and ameliorates financial stability gains. All financial stability measures favor a relatively concentrated market where the number of banks is between five and seven.

These findings have direct implications for policymakers. First, they validate the importance of considering financial stability in the banking consolidation debate. Second, they support active policies to control the number of banks according to the banks' and policymakers' objectives, e.g., Canadian and Australian policies to lower banking sector competition.

Further investigation of heterogeneous bank sizes, market power, and banks that are too big to fail, can be explored using a more detailed model. Future research can consider observing banking efficiency, fintech, new entries, and accessibility for households and firms in this context.

References

Allen, F., Gale, D., 2004a. Competition and financial stability. Journal of Money, Credit and Banking 36 (3), 453–480.

Allen, F., Gale, D., 2004b. Financial intermediaries and markets. Econometrica 72 (4), 1023–1061.

Angeloni, I., Faia, E., 2013. Capital regulation and monetary policy with fragile banks. Journal of Monetary Economics 60 (3), 311–324.

Beck, T., De Jonghe, O., Schepens, G., 2013. Bank competition and stability: Cross-country heterogeneity. Journal of Financial Intermediation 22 (2), 218–244.

Beck, T., Demirguc-Kunt, A., Levine, R., 2006. Bank concentration, competition, and crises: First results. Journal of Banking & Finance 30 (5), 1581–1603.

Berger, A. N., Mester, L. J., 1997. Inside the black box: What explains differences in the efficiencies of financial institutions? Journal of Banking & Finance 21 (7), 895–947.

Bernanke, B., Gertler, M., Gilchrist, S., 1999. The financial accelerator in a quantitative business cycle framework. In: Taylor, J. B., Woodford, M. (Eds.), Handbook of macroeconomics. Elsevier, Ch. 21, pp. 1341–1393.

Boyd, J. H., De Nicoló, G., 2005. The theory of bank risk taking and competition revisited. Journal of Finance 60 (3), 1329–1343.

Brown, C., Do, V., Trevarthen, O., 2017. Liquidity shock management: Lessons from Australian banks. Australian Journal of Management 42 (4), 637–652.

Brunnermeier, M. K., Sannikov, Y., 2014. A macroeconomic model with a financial sector. American Economic Review 104 (2), 379–421.

Brzoza-Brzezina, M., Kolasa, M., Makarski, K., 2013. The anatomy of standard DSGE models with financial frictions. Journal of Economic Dynamics and Control 37 (1), 32–51.

Cobb, C., Douglas, P., 1928. A theory of production. American Economic Review 18 (1), 139–165.

Colciago, A., Etro, F., 2010. Real business cycles with Cournot competition and endogenous entry. Journal of Macroeconomics 32 (4), 1101–1117.

Corbae, D., Levine, R., 2022. Competition, stability, and efficiency in the banking industry. mimeo, University of Wisconsin.

Cuciniello, V., Signoretti, F. M., 2015. Large banks, loan rate markup, and monetary policy. International Journal of Central Banking 11 (3), 141–177.

Curti, F., Frame, W. S., Mihov, A. A., 2022. Are the largest banking organizations operationally more risky? Forthcoming, Journal of Money, Credit and Banking.

Darracq Pariès, M., Kok, C., Rodriguez-Palenzuela, D., 2011. Macroeconomic propagation under different regulatory regimes: evidence from an estimated DSGE model for the Euro area. International Journal of Central Banking 7 (4), 49–113.

Faia, E., 2012. Oligopolistic competition and optimal monetary policy. Journal of Economic Dynamics and Control 36 (11), 1760–1774.

Fernández de Guevara, J., Maudos, J., 2007. The cost of market power in banking: Social welfare loss vs. cost inefficiency. Journal of Banking & Finance 31 (7), 2103–2125.

Fernández de Guevara, J., Maudos, J., Pérez, F., April 2005. Market power in European banking sectors. Journal of Financial Services Research 27 (2), 109–137.

Galí, J., 2008. Monetary policy, inflation and the business cycle: an introduction to the New Keynesian framework, 1st Edition. Princeton, NJ: Princeton University Press.

Gerali, A., Neri, S., Sessa, L., Signoretti, F., 2010. Credit and banking in a DSGE model of the Euro area. Journal of Money, Credit and Banking 42 (6), 107–141.

Hafeez, B., Li, X., Kabir, M. H., Tripe, D., 2022. Measuring bank risk: Forward-looking z-score. International Review of Financial Analysis 80 (C).

Iacoviello, M., 2005. House prices, borrowing constraints, and monetary policy in the business cycle. American Economic Review 95 (3), 739–764.

Iacoviello, M., 2015. Financial business cycles. Review of Economic Dynamics 18 (1), 140–164.

Iacoviello, M., Neri, S., 2010. Housing market spillovers: evidence from an estimated DSGE model. American Economic Journal: Macroeconomics 2 (2), 125–164.

Jeasakul, P., Lim, C. H., Lundback, E. J., 2014. Why was Asia resilient? Lessons from the past and for the future. IMF Working Papers 2014/038, International Monetary Fund.

Keeley, M. C., 1990. Deposit insurance, risk, and market power in banking. American Economic Review 80 (5), 1183–1200.

Kiley, M. T., Sim, J., 2017. Optimal monetary and macroprudential policies: Gains and pitfalls in a model of financial intermediation. Journal of Macroeconomics 54 (PB), 232–259.

Kiyotaki, N., Moore, J., 1997. Credit cycles. Journal of Political Economy 105 (2), 211–248.

Kollmann, R., Enders, Z., Müller, G. J., 2011. Global banking and international business cycles. European Economic Review 55 (3), 407–426.

Lucchetta, M., 2017. Banking competition and welfare. Annals of Finance 13 (1), 31–53.

Meh, C. A., Moran, K., 2010. The role of bank capital in the propagation of shocks. Journal of Economic Dynamics and Control 34 (3), 555–576.

Mendicino, C., Nikolov, K., Suarez, J., Supera, D., 2018. Optimal dynamic capital requirements. Journal of Money, Credit and Banking 50 (6), 1271–1297.

Mishkin, F. S., 1999. Financial consolidation: Dangers and opportunities. Journal of Banking & Finance 23 (2-4), 675–691.

Nouy, D., 2017. Too much of a good thing? The need for consolidation in the European banking sector. Tech. Rep. Speech, VIII Financial Forum, Madrid, 27 September.

Pfeifer, J., 2019. A guide to specifying observation equations for the estimation of DSGE models. University of Cologne.

Rotemberg, J. J., 1982a. Monopolistic price adjustment and aggregate output. Review of Economic Studies 49 (4), 517–31.

Rotemberg, J. J., 1982b. Sticky prices in the United States. Journal of Political Economy 90 (6), 1187–1211.

Smets, F., Wouters, R., 2003. An estimated dynamic stochastic general equilibrium model of the Euro area. Journal of the European Economic Association 1 (5), 1123–1175.

Smets, F., Wouters, R., 2005. Comparing shocks and frictions in US and euro area business cycles: a Bayesian DSGE approach. Journal of Applied Econometrics 20 (2), 161–183.

Smets, F., Wouters, R., 2007. Shocks and frictions in US business cycles: a Bayesian DSGE approach. American Economic Review 97 (3), 586–606.

Taylor, J. B., 1993. Discretion versus policy rules in practice. Carnegie-Rochester Conference Series on Public Policy 39 (1), 195–214.

U-Din, S., Tripe, D., Kabir, M. H., 2022. Bank size, competition, and efficiency: a post-GFC assessment of Australia and New Zealand. New Zealand Economic Papers 56 (2), 195–217.

Vives, X., 2016. Competition and stability in banking: the role of regulation and competition policy. Princeton, NJ: Princeton University Press.

Appendix

A Benchmark Model

A.1 Patient Households

Patient households p work, consume, and accumulate housing services to maximize their utility, according to the following objective function:

$$\mathbb{E}_0 \sum_{k=0}^{\infty} \beta_p^k \left(\epsilon_t^z \ln\left(c_{p,t+k}\right) + j \ln\left(h_{p,t+k}\right) - \frac{l_{p,t+k}^{1+\varphi}}{1+\varphi} \right), \tag{46}$$

where $c_{p,t}$ denotes the current consumption, $h_{p,t}$ denotes housing services, and $l_{p,t}$ are the working hours of patient households. j denotes housing weight in household's preferences, and φ is the disutility of labor–inverse for the Frisch elasticity. β_p is the patient households' discount factor, and ϵ_t^z is a preference shock that affects consumption detailed in section A.8.

Patient households maximize their utility function (Eq. 46) relative to their following budget constraint

$$c_{p,t} + q_{h,t}\left(h_{p,t} - h_{p,t-1}\right) + d_t = \frac{1+R_{t-1}^d}{\pi_t} d_{t-1} + w_{p,t} l_{p,t} + J_{r,t}, \tag{47}$$

where $q_{h,t} = Q_{h,t}/P_t$ is the real housing price and $Q_{h,t}$ is nominal housing price. $\pi_t$is the gross inflation rate and d_t is the amount of deposits remunerated at the nominal rate R_t^d, and $w_{p,t} = W_{p,t}/P_t$ is the real wage of patient households. Lump-sum transfers contain dividends from retailers $J_{r,t}$.

Optimality conditions of patient households' maximization of their utility (Eq. 46) subject to their budget constraint (Eq. 47) are

$$\frac{\epsilon_t^z}{c_{p,t}} = \beta_p \mathbb{E}_t \left[\frac{1+R_t^d}{\pi_{t+1}} \epsilon_{t+1}^z \frac{1}{c_{p,t+1}} \right], \tag{48}$$

$$\frac{j}{h_{p,t}} = \frac{q_{h,t}\epsilon_t^z}{c_{p,t}} - \beta_p \mathbb{E}_t \left[q_{h,t+1} \epsilon_{t+1}^z \frac{1}{c_{p,t+1}} \right], \tag{49}$$

$$l_{p,t}^{\varphi} = w_{p,t} \epsilon_t^z \frac{1}{c_{p,t}}. \tag{50}$$

A.2 Impatient Households

Impatient households i work, consume, and accumulate housing services to maximize Their utility according to the following objective function:

$$\mathbb{E}_0 \sum_{k=0}^{\infty} \beta_i^k \left(\epsilon_t^z \ln\left(c_{i,t+k}\right) + j \ln\left(h_{i,t+k}\right) - \frac{l_{i,t+k}^{\varphi+1}}{\varphi+1} \right), \tag{51}$$

where $c_{i,t}$ denotes current consumption, $h_{i,t}$ housing services, and $l_{i,t}$ hours worked by impatient households. β_i denotes impatient households' discount factor. The only difference between the two types of households is linked to their degree of impatience: impatient households discount the future more heavily than patient ones, which implies that β_i is smaller than β_p (Iacoviello, 2005; Gerali et al., 2010). ϵ_t^z is the same preference shock experienced by both the households.

Impatient household decisions are made according to the following budget constraint

$$c_{i,t} + q_{h,t}\left(h_{i,t} - h_{i,t-1}\right) + \frac{1 + R_{t-1}^{b_i}}{\pi_t} b_{i,t-1} = b_{i,t} + w_{i,t} l_{i,t}, \tag{52}$$

where $b_{i,t}$ denotes impatient household's loans, $R_t^{b_i}$ is the nominal interest rate on loans, and $w_{i,t}$ denotes the impatient households' real wages.

In our model, financial frictions arise from collateral constraint. (Kiyotaki and Moore, 1997; Iacoviello, 2005; Gerali et al., 2010). This constraint forces borrowers to own a part of their borrowings in the form of collateral assets. For impatient households, this collateral constraint is based on the amount of real estate and can be written as

$$\left(1 + R_t^{b_i}\right) b_{i,t} \leq m_{i,t} \mathbb{E}_t \left[q_{h,t+1} h_{i,t} \pi_{t+1}\right], \tag{53}$$

where $m_{i,t}$ is the loan-to-value (LTV) ratio detailed in Section A.8. A positive shock to $m_{i,t}$ is interpreted as collateral constraint-tightening. This facilitates analyzing the impact of a credit rationing scenario on the economy. Eq. 53 implies that if the borrower fails to pay their debt, the lender can acquire their assets by paying a proportional transaction cost.[22] Impatient households are constrained to borrow $b_{i,t}$ to a certain limit.[23]

[22]Equal to $\left(1 - m_{i,t}\right) \mathbb{E}_t \left[q_{h,t+1} h_{i,t} \pi_{t+1}\right]$

[23]Equal to $m_{i,t} \mathbb{E}_t \left[q_{h,t+1} h_{i,t} \pi_{t+1} / \left(1 + R_t^{b_i}\right)\right]$

The optimality conditions of impatient households' maximization of their utility (Eq. 51) subject to their budget (Eq. 52) and collateral (Eq. 53) constraints are

$$\epsilon_t^z \frac{1}{c_{i,t}} = \beta_i \mathbb{E}_t \left[\frac{1+R_t^{b_i}}{\pi_{t+1}} \epsilon_{t+1}^z \frac{1}{c_{i,t+1}} \right] + \lambda_{i,t} \left(1+R_t^{b_i}\right), \tag{54}$$

$$\frac{j}{h_{i,t}} = q_{h,t}\epsilon_t^z \frac{1}{c_{i,t}} - \beta_i \mathbb{E}_t \left[q_{h,t+1}\epsilon_{t+1}^z \frac{1}{c_{i,t+1}} + \lambda_{i,t} m_{i,t} q_{h,t+1} \pi_{t+1} \right], \tag{55}$$

$$l_{i,t}^{\varphi} = w_{i,t}\epsilon_t^z \frac{1}{c_{i,t}}. \tag{56}$$

A.3 Entrepreneurs

Entrepreneurs produce intermediate goods according to the following Cobb and Douglas (1928) production function

$$y_t = A_t k_{e,t-1}^{\alpha} l_{p,t}^{\mu(1-\alpha)} l_{i,t}^{(1-\mu)(1-\alpha)}, \tag{57}$$

where y_t represents intermediate goods, and $k_{e,t}$ is the productive capital. α is the share of capital in the production function and μ is the share of patient household's labor. A_t is the technology shock detailed in section A.8.

Entrepreneurs e maximize their utility, which depends solely on consumption, according to the following objective function

$$\mathbb{E}_0 \sum_{k=0}^{\infty} \beta_e^k \ln\left(c_{e,t+k}\right), \tag{58}$$

where $c_{e,t}$ denotes entrepreneurs' consumption, and β_e denotes the entrepreneurs' discount factors. For impatient households, entrepreneurs are considered borrowers and, therefore, discount the future more heavily than lenders, such that the discount factor β_e should be lower than that of patient households ($\beta_e < \beta_p$).

Entrepreneurs' decisions are based on the following budget constraint

$$c_{e,t} + \frac{1+R_{t-1}^{b_e}}{\pi_t} b_{e,t-1} + w_{p,t} l_{p,t} + w_{i,t} l_{i,t} + q_{ke,t} k_{e,t} = \frac{y_t}{x_t} + b_{e,t} + q_{ke,t}\left(1-\delta_{ke}\right) k_{e,t-1}, \tag{59}$$

where $b_{e,t}$ denotes entrepreneurs' loans, $R_t^{b_e}$ the nominal interest rate on loans, $q_{ke,t}$ the real price of capital, δ_{ke} the capital depreciation rate, and x_t the markup of final over intermediate goods.

For impatient households, we assume that the entrepreneurs' collateral value restricts the amount they can borrow, given by their holdings of physical capital. The entrepreneur collateral constraint follows

$$\left(1 + R_t^{b_e}\right) b_{e,t} \leq \mathbb{E}_t \left[m_{e,t} q_{ke,t+1} \left(1 - \delta_{ke}\right) k_{e,t} \pi_{t+1}\right], \tag{60}$$

where $m_{e,t}$ is the entrepreneur's LTV detailed in Section A.8.

Finally, the optimality conditions of entrepreneurs' maximization of their utility (Eq. 58) subject to their budget constraint (Eq. 59), collateral constraint (Eq. 60), and production function (Eq. 57) are

$$\frac{1}{c_{e,t}} = \beta_e \mathbb{E}_t \left[\frac{1 + R_t^{b_e}}{\pi_{t+1}} \frac{1}{c_{e,t+1}}\right] + \lambda_{e,t} \left(1 + R_t^{b_e}\right), \tag{61}$$

$$\frac{1}{c_{e,t}} q_{ke,t} = \beta_e \mathbb{E}_t \left[\begin{array}{c} \frac{1}{c_{e,t+1}} \left(\alpha \frac{y_{t+1}}{x_{t+1} k_{e,t}} + q_{ke,t+1} \left(1 - \delta_{ke}\right)\right) \\ + \lambda_{e,t} m_{e,t} q_{ke,t+1} \pi_{t+1} \left(1 - \delta_{ke}\right) \end{array}\right], \tag{62}$$

$$w_{p,t} = \frac{\mu \left(1 - \alpha\right)}{l_{p,t}} \frac{y_t}{x_t}, \tag{63}$$

$$w_{i,t} = \frac{\left(1 - \mu\right) \left(1 - \alpha\right)}{l_{i,t}} \frac{y_t}{x_t}. \tag{64}$$

A.4 Retail Sector

Following Bernanke et al. (1999) and Iacoviello (2005), we assume that goods produced by entrepreneurs cannot be consumed immediately. They are first sold to retailers at wholesale prices $P_{w,t}$. Retailers differentiate them into final goods at no cost and sell them to consumers at the market price P_t. Under this assumption, $x_t = P_t / P_{w,t}$ denotes the markup of final goods over that of intermediate goods.

Retailers z bundle intermediate goods y_t according to the following CES technology

$$y_t = \left[\int_0^1 y_t\left(z\right)^{\frac{\epsilon_t - 1}{\epsilon_t}} dz\right]^{\frac{\epsilon_t}{\epsilon_t - 1}}, \tag{65}$$

where ϵ_t is the elasticity of substitution between intermediate goods, detailed in Section A.8.

Given the aggregate output index (Eq. 65), the price index is P_t is

$$P_t = \left[\int_0^1 P_t\left(z\right)^{1 - \epsilon_t} dz\right]^{\frac{1}{1 - \epsilon_t}}, \tag{66}$$

such that each retailer faces an individual demand curve:

$$y_t(z) = \left(\frac{P_t(z)}{P_t}\right)^{-\epsilon_t} y_t. \tag{67}$$

Retailers choose $P_t(j)$ to maximize

$$\mathbb{E}_t \sum_{k=0}^{\infty} \Lambda_{t,k}^{p} \left[P_t(z) y_t(z) - P_t^{w} y_t(z) - \frac{\kappa_p}{2} \left(\frac{P_t(z)}{P_{t-1}(z)} - \pi_{t-1}^{\iota_p} \pi^{1-\iota_p} \right)^2 P_t y_t \right], \tag{68}$$

where $\Lambda_{t,k}^{p} = \beta_p U_{c,t+k}/U_{c,t}$ denotes the stochastic discount factor, assuming the demand curve (Eq. 67) and wholesale price P_t^w as given.

The optimality condition associated with the retailers' problem is detailed in Appendix A.4. In our model, a positive shock to ϵ_t leads to a decrease in the optimal value of markups, which can be interpreted as a negative price markup shock.

$$\begin{aligned} 1 - \epsilon_t + \tfrac{\epsilon_t}{X_t} - \kappa_p \left(\pi_t - \pi_{t-1}^{\iota_p} \pi^{1-\iota_p} \right) \pi_t \\ + \beta_p \left(\tfrac{\epsilon_{t+1}^z}{\epsilon_t^z} \tfrac{c_{i,t}}{c_{i,t+1}} \right) \kappa_p \left(\pi_{t+1} - \pi_t^{\iota_p} \pi^{1-\iota_p} \right) \pi_{t+1} \tfrac{y_{t+1}}{y_t} = 0. \end{aligned} \tag{69}$$

A.5 Capital Goods Producers

At the beginning of each period, capital producers buy an amount i_t of final goods and the stock of old undepreciated capital $(1-\delta_{ke}) k_{e,t-1}$ from entrepreneurs.[24]

The amount of capital goods produced is

$$k_{e,t} = (1-\delta_{ke}) k_{e,t-1} + \left[1 - \frac{\kappa_i}{2} \left(\frac{\epsilon_t^{qk} i_t}{i_{t-1}} - 1 \right)^2 \right] i_t, \tag{70}$$

where κ_i is the adjustment cost of a change in investment and ϵ_t^{qk} is a shock to investment efficiency, detailed in Section A.8,

The new capital is sold to entrepreneurs at a nominal market price of capital Q_k. We assume a perfectly competitive capital market where the capital goods producers' profit maximization yields the following dynamic equation similar to Smets and Wouters (2003, 2007) for the real price of capital. The optimality

[24] We assume that old capital can be converted into new capital and that the transformation of the final good is subject to quadratic adjustment costs.

condition is

$$1 = q_{k,t}\left(1-\frac{\kappa_i}{2}\left(\frac{\epsilon_t^{qk} i_t}{i_{t-1}}-1\right)^2-\kappa_i\left(\frac{\epsilon_t^{qk} i_t}{i_{t-1}}-1\right)\left(\frac{\epsilon_t^{qk} i_t}{i_{t-1}}\right)\right)$$
$$+\beta_e\left(\frac{c_{e,t}}{c_{e,t+1}}\right) q_{k,t+1}\kappa_i\left(\frac{\epsilon_{t+1}^{qk} i_{t+1}}{i_t}-1\right)\left(\frac{\epsilon_{t+1}^{qk} i_{t+1}}{i_t}\right)^2. \quad (71)$$

A.6 Monetary Policy

The model is closed with the following standard monetary policy reaction function *à la* Taylor (1993)

$$1+R_t = (1+R_{t-1})^{\rho_R}\left(\left(\frac{\pi}{\overline{\overline{\pi}}}\right)^{\rho_\pi}\left(\frac{y_t}{y_{t-1}}\right)^{\rho_y}(1+\overline{R})\right)^{1-\rho_R}(1+\varepsilon_{r,t}), \quad (72)$$

where ρ_π and ρ_y reflect the central bank's policy weights on inflation and output gap, respectively. Parameter $\rho_R \in]0;1[$ captures the degree of interest rate smoothing, $\varepsilon_{r,t}$ exogenous fluctuations in the nominal interest rate, and $\overline{\pi}$ denotes steady-state inflation rate.

A.7 Equilibrium

Equilibrium in the goods market is

$$y_t = c_{p,t} + c_{i,t} + c_{e,t} + i_t, \quad (73)$$

and the equilibrium in the housing market is

$$h_{p,t} + h_{i,t} = 1. \quad (74)$$

Aggregate labor is

$$l_t = l_{p,t} + l_{i,t}, \quad (75)$$

and the aggregate wage is

$$w_t = \frac{(w_{p,t} + w_{i,t})}{2}. \quad (76)$$

A.8 Stochastic Structure

Structural shocks are assumed to follow an AR(1) functional form, such that

$$X_t = (1 - \rho_X)\,\overline{X} + \rho_X X_{t-1} + \eta_t^X, \tag{77}$$

where $X_t \in \left\{\epsilon_t^z, A_{e,t}, m_{i,t}, m_{e,t}, \epsilon_t, \epsilon_t^{qk}\right\}$, $\overline{X}$ is the steady-state value of X_t, $\rho_X \in [0,1[$ is the first-order, autoregressive parameter of shock X_t and innovation η_t^X is an *i.i.d.* normal error term with zero mean and standard deviation σ_X.

B Model Summary

B.1 Patient households

$$c_{p,t} + q_{h,t}\left(h_{p,t} - h_{p,t-1}\right) + d_t = \frac{1 + R_{t-1}^d}{\pi_t} d_{t-1} + w_{p,t} l_{p,t} + J_{r,t}, \tag{78}$$

$$\frac{\epsilon_t^z}{c_{p,t}} = \beta_p \mathbb{E}_t\left[\frac{1 + R_t^d}{\pi_{t+1}} \epsilon_{t+1}^z \frac{1}{c_{p,t+1}}\right], \tag{79}$$

$$\frac{j}{h_{p,t}} = \frac{q_{h,t}\epsilon_t^z}{c_{p,t}} - \beta_p \mathbb{E}_t\left[q_{h,t+1}\epsilon_{t+1}^z \frac{1}{c_{p,t+1}}\right], \tag{80}$$

$$l_{p,t}^{\varphi} = w_{p,t}\epsilon_t^z \frac{1}{c_{p,t}}. \tag{81}$$

B.2 Impatient households

$$c_{i,t} + q_{h,t}\left(h_{i,t} - h_{i,t-1}\right) + \frac{1 + R_{t-1}^{b_i}}{\pi_t} b_{i,t-1} = b_{i,t} + w_{i,t} l_{i,t}, \tag{82}$$

$$\left(1 + R_t^{b_i}\right) b_{i,t} \leq m_{i,t} \mathbb{E}_t\left[q_{h,t+1} h_{i,t} \pi_{t+1}\right], \tag{83}$$

$$\epsilon_t^z \frac{1}{c_{i,t}} = \beta_i \mathbb{E}_t\left[\frac{1 + R_t^{b_i}}{\pi_{t+1}} \epsilon_{t+1}^z \frac{1}{c_{i,t+1}}\right] + \lambda_{i,t}\left(1 + R_t^{b_i}\right), \tag{84}$$

$$\frac{j}{h_{i,t}} = q_{h,t}\epsilon_t^z \frac{1}{c_{i,t}} - \beta_i \mathbb{E}_t\left[q_{h,t+1}\epsilon_{t+1}^z \frac{1}{c_{i,t+1}} + \lambda_{i,t} m_{i,t} q_{h,t+1} \pi_{t+1}\right], \tag{85}$$

$$l_{i,t}^{\varphi} = w_{i,t}\epsilon_t^z \frac{1}{c_{i,t}}. \tag{86}$$

B.3 Entrepreneurs

$$y_t = A_t k_{e,t-1}^{\alpha} l_{p,t}^{\mu(1-\alpha)} l_{i,t}^{(1-\mu)(1-\alpha)}, \tag{87}$$

$$\begin{aligned} c_{e,t} + \tfrac{1+R_{t-1}^{b_e}}{\pi_t} b_{e,t-1} + w_{p,t} l_{p,t} + w_{i,t} l_{i,t} + q_{ke,t} k_{e,t} \\ = \tfrac{y_t}{x_t} + b_{e,t} + q_{ke,t} \left(1-\delta_{ke}\right) k_{e,t-1}, \end{aligned} \tag{88}$$

$$\left(1+R_t^{b_e}\right) b_{e,t} \leq \mathbb{E}_t \left[m_{e,t} q_{ke,t+1} \left(1-\delta_{ke}\right) k_{e,t} \pi_{t+1}\right], \tag{89}$$

$$\frac{1}{c_{e,t}} = \beta_e \mathbb{E}_t \left[\frac{1+R_t^{b_e}}{\pi_{t+1}} \frac{1}{c_{e,t+1}}\right] + \lambda_{e,t} \left(1+R_t^{b_e}\right), \tag{90}$$

$$\frac{1}{c_{e,t}} q_{ke,t} = \beta_e \mathbb{E}_t \left[\begin{array}{c} \frac{1}{c_{e,t+1}} \left(\alpha \frac{y_{t+1}}{x_{t+1} k_{e,t}} + q_{ke,t+1} \left(1-\delta_{ke}\right)\right) \\ +\lambda_{e,t} m_{e,t} q_{ke,t+1} \pi_{t+1} \left(1-\delta_{ke}\right) \end{array}\right], \tag{91}$$

$$w_{p,t} = \frac{\mu\left(1-\alpha\right)}{l_{p,t}} \frac{y_t}{x_t}, \tag{92}$$

$$w_{i,t} = \frac{\left(1-\mu\right)\left(1-\alpha\right)}{l_{i,t}} \frac{y_t}{x_t}. \tag{93}$$

B.4 Retailers

$$\left[y_t \left(1 - \frac{1}{x_t} - \frac{\kappa_p}{2} \left(\pi_t - \pi_{t-1}^{\iota_p} \pi^{1-\iota_p}\right)^2\right)\right], \tag{94}$$

$$\begin{aligned} 1 - \epsilon_t + \tfrac{\epsilon_t}{X_t} - \kappa_p \left(\pi_t - \pi_{t-1}^{\iota_p} \pi^{1-\iota_p}\right) \pi_t \\ +\beta_p \left(\tfrac{\epsilon_{t+1}^z}{\epsilon_t^z} \tfrac{c_{i,t}}{c_{i,t+1}}\right) \kappa_p \left(\pi_{t+1} - \pi_t^{\iota_p} \pi^{1-\iota_p}\right) \pi_{t+1} \tfrac{y_{t+1}}{y_t} = 0. \end{aligned} \tag{95}$$

B.5 Capital producers

$$k_{e,t} = (1-\delta_{ke}) k_{e,t-1} + \left[1 - \frac{\kappa_i}{2} \left(\frac{\epsilon_t^{qk} i_t}{i_{t-1}} - 1\right)^2\right] i_t, \tag{96}$$

$$\begin{aligned} 1 \ &= q_{k,t} \left(1 - \tfrac{\kappa_i}{2} \left(\tfrac{\epsilon_t^{qk} i_t}{i_{t-1}} - 1\right)^2 - \kappa_i \left(\tfrac{\epsilon_t^{qk} i_t}{i_{t-1}} - 1\right) \left(\tfrac{\epsilon_t^{qk} i_t}{i_{t-1}}\right)\right) \\ &\quad +\beta_e \left(\tfrac{c_{e,t}}{c_{e,t+1}}\right) q_{k,t+1} \kappa_i \left(\tfrac{\epsilon_{t+1}^{qk} i_{t+1}}{i_t} - 1\right) \left(\tfrac{\epsilon_{t+1}^{qk} i_{t+1}}{i_t}\right)^2. \end{aligned} \tag{97}$$

B.6 Monetary policy

$$1+R_t = (1+R_{t-1})^{\rho_R} \left(\left(\frac{\pi}{\overline{\overline{\pi}}} \right)^{\rho_\pi} \left(\frac{y_t}{y_{t-1}} \right)^{\rho_y} (1+\overline{R}) \right)^{1-\rho_R} (1+\varepsilon_{r,t}). \tag{98}$$

B.7 Wholesale bank

$$K_{b,t} + D_t = B_t, \tag{99}$$

$$\pi_t K_{b,t} = (1-\delta_b) K_{b,t-1} + J_{b,t-1}, \tag{100}$$

$$R_{b,t} - R_t = -\kappa_{kb} \left(\frac{K_{b,t}}{B_t} - v \right) \left(\frac{K_{b,t}}{B_t} \right)^2, \tag{101}$$

$$J_{b,t} = R_t^{b_i} b_{i,t} + R_t^{b_e} b_{e,t} - R_t^d d_t - adj_t. \tag{102}$$

B.8 Deposit branch

$$R_t^d = R_t \frac{\varsigma_{d,t}}{\varsigma_{d,t} - 1}. \tag{103}$$

B.9 Loan branch: Monopolistic competition

$$R_t^{b_k} = R_{b,t} \frac{\varsigma_{b_k,t}}{\varsigma_{b_k,t} - 1}. \tag{104}$$

B.10 Loan branch: Cournot competition

$$R_t^{b_k} = R_{b,t} \frac{N}{(N-1)} \frac{\varsigma_{b_{k,t}}}{\varsigma_{b_{k,t}} - 1}. \tag{105}$$

B.11 Loan branch: Bertrand competition

$$R_t^{b_k} = R_{b,t} \frac{\left(\varsigma_{b_{k,t}} (1-N) - 1 \right)}{\left(1 - \varsigma_{b_{k,t}} \right) (N-1)}. \tag{106}$$

B.12 Equilibrium

$$y_t = c_{p,t} + c_{i,t} + c_{e,t} + i_t, \tag{107}$$

$$h_{p,t} + h_{i,t} = 1, \tag{108}$$

$$l_t = l_{p,t} + l_{i,t}, \tag{109}$$

$$w_t = \frac{\left(w_{p,t} + w_{i,t}\right)}{2}. \tag{110}$$

C Steady-State

We can always normalize the technology parameter A, such that $y = 1$ is in steady-state and express all variables as a ratio to y (Iacoviello, 2005).

$$y = 1, \tag{111}$$

$$\pi = 1, \tag{112}$$

$$q_k = 1, \tag{113}$$

$$R^d = \frac{\pi}{\beta} - 1, \tag{114}$$

$$x = \frac{\epsilon}{\epsilon - 1}, \tag{115}$$

$$J_r = y\left(1 - \frac{1}{x}\right), \tag{116}$$

$$R = \frac{\varsigma_{d,t} - 1}{\varsigma_{d,t}} R^d, \tag{117}$$

$$R_b = R \tag{118}$$

$$b_e = \frac{\beta^e \mu Y m_e \pi \left(1 - \delta_k\right)}{x\left(1 + R^{b_e}\right)} \frac{1}{1 - \beta_e\left(1 - \delta_k\right) - \left(\frac{1}{1+R^{e_e}} - \frac{\beta_e}{\pi}\right) m_e \pi \left(1 - \delta_k\right)}, \tag{119}$$

$$B = b_e + b_i, \tag{120}$$

$$K_b = Bv, \tag{121}$$

$$k_e = \frac{\left(1 + R^{b_e}\right) b_e}{m_e \pi q_k \left(1 - \delta_k\right)}, \tag{122}$$

$$i = \delta_k k_e, \tag{123}$$

$$d = b_e + b_i - K_b, \tag{124}$$

$$J_b = R^{b_e} b_e + R^{b_i} b_i - R^d d - \frac{\kappa_{kb}}{2} \left(\frac{K_b}{B} - v \right)^1 K_b, \tag{125}$$

$$c_p = d \left(\frac{1 + R^d}{\pi} - 1 \right) + \alpha \left(1 - \mu\right) \frac{y}{x} + \left(1 - \frac{1}{x}\right) Y + j_{cb}, \tag{126}$$

$$c_i = b_i \left(1 - \frac{1 + R^{b_i}}{\pi} \right) + \left(1 - \alpha\right) \left(1 - \mu\right) \frac{y}{x} + j_{cb}, \tag{127}$$

$$c_e = \frac{y}{x} + b_e \left(1 - \frac{1 + R^{b_e}}{\pi} \right) - \alpha \left(1 - \mu\right) \frac{y}{x} - \left(1 - \alpha\right) \left(1 - \mu\right) \frac{y}{x} - q_k k_e \delta_k + j_{cb}, \tag{128}$$

$$\lambda_i = \frac{1}{c_i} \left(\frac{1}{\left(1 + R^{b_i}\right)} - \frac{\beta_i}{\pi} \right), \tag{129}$$

$$\lambda_e = \frac{1}{c_e} \left(\frac{1}{\left(1 + R^{b_e}\right)} - \frac{\beta_e}{\pi} \right), \tag{130}$$

$$h_p = \frac{j c_p}{\left(1 - \beta_p\right)} \left(\frac{1}{q_h} \right), \tag{131}$$

$$h_i = \frac{b_i \left(1 + R^{b_i}\right)}{m_i \pi} \left(\frac{1}{q_h} \right), \tag{132}$$

$$q_h = \frac{j c_p}{\left(1 - \beta_p\right)} + \frac{b_i \left(1 + R^{b_i}\right)}{m_i \pi}, \tag{133}$$

$$w_p = \alpha \left(1 - \mu\right) \frac{y}{x l_p}, \tag{134}$$

$$l_p = \left(\alpha \left(1 - \mu\right) \frac{y}{x} \frac{1}{c_p} \right)^{1/(\varphi + 1)}, \tag{135}$$

$$w_i = \left(1 - \alpha\right) \left(1 - \mu\right) \frac{y}{x l_i}, \tag{136}$$

$$l_i = \left(\left(1 - \alpha\right) \left(1 - \mu\right) \frac{y}{x} c_i^{-\sigma_i} \right)^{1/(\varphi + 1)}, \tag{137}$$

$$A = \frac{Y}{k_e^{\mu} l_p^{\alpha(1-\mu)} l_i^{(1-\alpha)(1-\mu)}}, \tag{138}$$

$$l = l_p + l_i, \tag{139}$$

$$w = w_p + w_i. \tag{140}$$

Under MC,

$$R^{b_i} = \frac{\varsigma_{b_i}}{\varsigma_{b_i} - 1} R_b, \tag{141}$$

$$R^{b_e} = \frac{\varsigma_{b_e}}{\varsigma_{b_e} - 1} R_b. \tag{142}$$

Under CC,

$$R^{b_i} = \frac{\varsigma_{b_i}}{\varsigma_{b_i} - 1} R_b \frac{N}{N-1}, \tag{143}$$

$$R^{b_e} = \frac{\varsigma_{b_e}}{\varsigma_{b_e} - 1} R_b \frac{N}{N-1}. \tag{144}$$

Under BC,

$$R^{b_i} = \frac{\varsigma_{b_i} - \varsigma_{b_i} N + 1}{N - \varsigma_{b_i} N + \varsigma_{b_i} - 1} R_b, \tag{145}$$

$$R^{b_e} = \frac{\varsigma_{b_e} - \varsigma_{b_e} N + 1}{N - \varsigma_{b_e} N + \varsigma_{b_e} - 1} R_b. \tag{146}$$

D Data

This section presents the data used for empirical moment matching and measurement equations. Data transformations were performed to match model variables' moments to historical data moments. All the following data are collected from the Federal Reserve Bank of St. Louis (FRED). Code in parenthesis corresponds to the FRED identifier of the series.

D.1 Economic Data

Real gross domestic product: billions of chained 2012 dollars, quarterly, seasonally adjusted annual rate (GDPC1).
Real investment: fixed private investment, in billions of dollars, quarterly seasonally adjusted annual rate (FPI).
Labor: nonfarm business sector, average weekly hours, Index 2012=100, quarterly, seasonally adjusted (PRS85006023).
Price inflation: gross domestic product, implicit price deflator, Index 2012=100, quarterly, seasonally adjusted. (GDPDEF).
Real wage: nonfarm business sector: compensation per hour, Index 2012=100,

quarterly, seasonally adjusted (COMPNFB).
Real housing price: all transaction house price index for the United States; Index 1980:Q1=100, quarterly, not seasonally adjusted (USSTHPI).
Federal fund rate: effective Federal Funds Rate, percent, quarterly and not seasonally adjusted (FEDFUNDS).
Population: civilian noninstitutional population (CNP16OV).

D.2 Financial Data

(NCBDBIQ027S) : Nonfinancial corporate business, debt securities; Liability level, millions of dollars, not seasonally adjusted.
(BLNECLBSNNCB): Nonfinancial Corporate Business; Depository Institution Loans N.E.C.; Liability, Level; billions of dollars, not seasonally adjusted.
(OLALBSNNCB): Nonfinancial corporate business; other loans and advances; liability, billions of dollars, not seasonally adjusted.
(NNBDILNECL): Nonfinancial noncorporate business; depository institution loans not elsewhere classified; liability, billions of dollars, not seasonally adjusted.
(OLALBSNNB): Nonfinancial noncorporate business; other loans and advances; liability, level, billions of dollars, not seasonally adjusted.
(MLBSNNCB): Nonfinancial corporate business; total mortgages; liability, billions of dollars, not seasonally adjusted.
(NNBTML): Nonfinancial noncorporate business; total mortgages; liability, level, billions of dollars, not seasonally adjusted.
(HNOTMLQ027S): Households mortgage: households and nonprofit organizations; total mortgages; liability, level, millions of dollars, not seasonally adjusted.
(CCLBSHNO): Households consumer loans: households and nonprofit organizations; consumer credit; liability, level, billions of dollars, not seasonally adjusted.
(AAA): Moody's Seasoned AAA corporate bond yield: percentage, not seasonally adjusted.
(MPRIME): Bank Prime Loan Rate: percent, not seasonally adjusted.
(MORTGAGE30US): 30-Year Fixed-Rate Mortgage Average in the United States: percent, not seasonally adjusted.
(TERMCBAUTO48NS): Finance rate on consumer installment loans at commercial banks: new autos 48-month loan, percent, not seasonally adjusted.
Deposits (DEP): Deposits, all commercial banks, billions of U.S. dollars, seasonally adjusted (DPSACBM027SBOG).

Loan to firms (LTF) = (NCBDBIQ027S) + (BLNECLBSNNCB) + (OLALBSNNCB) + (NNBDILNECL) + (OLALBSNNB) + (MLBSNNCB) + (NNBTML).
Loan to households (LTHH) = (HNOTMLQ027S) + (CCLBSHNO).
Nominal interest rate on loans to firms (NIROLTF) = (AAA) × (NCBDBIQ027S)/LTF + (MPRIME) × ((BLNECLBSNNCB) + (OLALBSNNCB) + (NNBDILNECL) + (OLALBSNNB))/LTF + (MORTGAGE30US) × ((MLBSNNCB) + (NNBTML))/LTF.
Nominal interest rate on loans to households (NIROLTHH) = (MORTGAGE30US) × (HNOTMLQ027S)/LTHH + (TERMCBAUTO48NS) × (CCLBSHNO)/LTHH.

E Data Transformations

As in Smets and Wouters (2003, 2007), the following data transformations are required to estimate the model using relevant data

$$GDP_t = 100\ln\left(\frac{GDPC1_t}{CNP16OV_t}\right) \tag{147}$$

$$INV_t = 100\ln\left(\left(\frac{FPI_t}{GDPDEF_t}\right)CNP16OV_t^{-1}\right) \tag{148}$$

$$WAGE_t = 100\ln\left(\left(\frac{COMPNFB_t}{GDPDEF_t}\right)CNP16OV_t^{-1}\right) \tag{149}$$

$$LABOR_t = 100\ln\left(PRS85006023_t\left(\frac{CE16OV_t}{100}\right)CNP16OV_t^{-1}\right) \tag{150}$$

$$INF_t = 100\ln\left(\frac{GDPDEF_t}{GDPDEF_{t-1}}\right) \tag{151}$$

$$QINF_t = 100\ln\left(\left(\frac{USSTHPI_t}{GDPDEF_t}\right)CNP16OV_t^{-1}\right) \tag{152}$$

$$RATE_t = \frac{FEDFUNDS_t}{4} \tag{153}$$

$$HHRATE_t = \frac{NIROLTF_t}{4} \tag{154}$$

$$ENTRATE_t = \frac{NIROLTHH_t}{4} \tag{155}$$

$$ENTLOAN_t = 100\ln\left(\left(\frac{LTF_t}{GDPDEF_t}\right)CNP16OV_t^{-1}\right) \tag{156}$$

$$HHLOAN_t = 100\ln\left(\left(\frac{LTHH_t}{GDPDEF_t}\right)CNP16OV_t^{-1}\right) \tag{157}$$

$$DEPOSIT_t = 100 \ln \left(\left(\frac{DEP_t}{GDPDEF_t} \right) CNP16OV_t^{-1} \right) \tag{158}$$

where $CE16OV_t$ and $CNP16OV_t$ are transformed into indices of the same base.

F Measurement Equations

The following observable equations are in line with Darracq Pariès et al. (2011) and Pfeifer (2019).

$$GDP_{obs,t} = \ln \left(\frac{y_t}{y} \right) \tag{159}$$

$$INV_{obs,t} = \ln \left(\frac{i_t}{i} \right) \tag{160}$$

$$WAGE_{obs,t} = \ln \left(\frac{w_t}{w} \right) \tag{161}$$

$$LABOR_{obs,t} = \ln \left(\frac{l_t}{l} \right) \tag{162}$$

$$INF_{obs,t} = \ln (\pi_t) \tag{163}$$

$$QINF_{obs,t} = \ln \left(\frac{q_{h,t}}{q_h} \right) \tag{164}$$

$$RATE_{obs,t} = \left(100 \left(\frac{1+R_t}{1+R} - 1 \right) \right) \tag{165}$$

$$HH\_RATE_{obs,t} = \left(100 \left(\frac{1+R_t^{b_i}}{1+R^{b_i}} - 1 \right) \right) \tag{166}$$

$$ENT\_RATE_{obs,t} = \left(100 \left(\frac{1+R_t^{b_e}}{1+R^{b_e}} - 1 \right) \right) \tag{167}$$

$$ENT\_LOAN_{obs,t} = \ln \left(\frac{b_{e,t}}{b_e} \right) \tag{168}$$

$$HH\_LOAN_{obs,t} = \ln \left(\frac{b_{i,t}}{b_i} \right) \tag{169}$$

$$DEPOSIT_{obs,t} = \ln \left(\frac{d_t}{d} \right) \tag{170}$$

G Variance Decompositions

Forecast error variance decomposition indicates the proportion of error of each variable owing to each exogenous shock. We evaluate the effects of economic, financial, and monetary policy shocks on economic fluctuations under different bank competition scenarios. Theoretical variance decomposition results were simulated using a first-order approximation of our nonlinear models and provide results consistent with literature. Notably, our models relate the main characteristics of variance decomposition: the technology shock explains more than 40% of the variations in output, and price markup shock explains approximately 60% of variations in inflation. Beyond these findings validating our models, we analyzed the variance decomposition of financial shocks. We built a block of financial shocks that simultaneously consider the impact of all financial shocks (LTV and loan markup shock). We compared the contributions of financial shocks over different banking market structures, covering both competition types and concentration levels.

Table 6 presents the variance decompositions for the short- and long-term variables according to real, financial, and interest rate shocks in the MC model.

The variance decompositions in Table 6 are in line with literature and present interesting insights on the origins of financial stability ratios and bank markup dynamics.

Table 7 presents the variance decompositions for CC.

Table 8 presents the variance decompositions of BC model's variables with respect to real, financial, and interest rate shocks.

Table 8 shows that our model correctly replicates most of the variance decompositions of variables with respect to shocks.

H Deposit Markup Shock

Fig. 12 presents the responses of the economy to a deposit markup shock.

A positive deposit markup shock increases deposit rates, which attract money into deposit accounts, and lowers output, consumption, and investment. This increase in deposits decreases banking capital and, thus, affects the financial stability indicators. However, this increases short-run patient household welfare and medium-run impatient welfare. Households' and entrepreneurs' welfare under CC is higher than that under BC.

Figure 12: Response to a 1% deposit markup shock shock (in %)

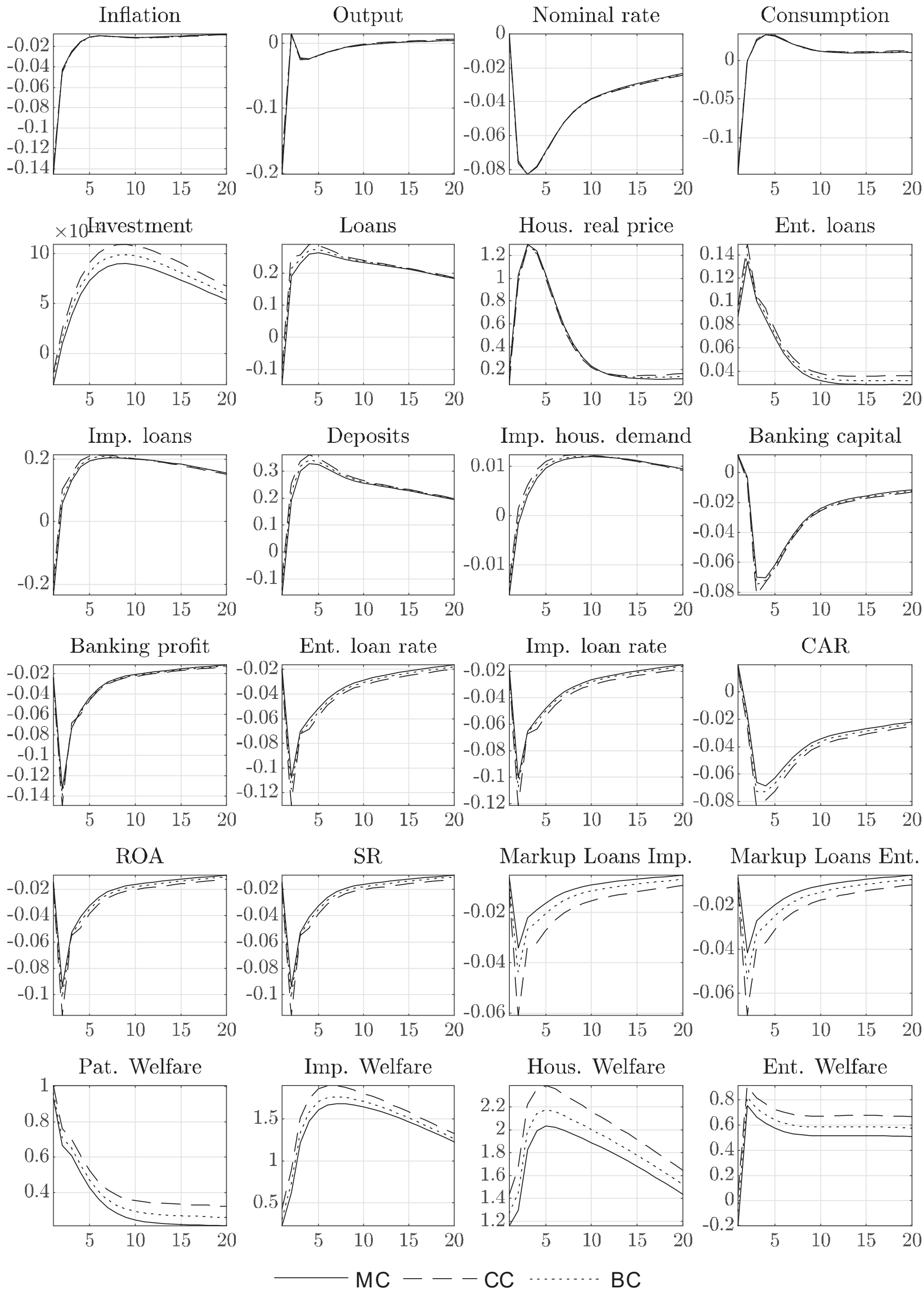


Table 6: Variance Decompositions: MC

	Long run			Short run		
	Real	Financial	Interest Rate	Real	Financial	Interest Rate
Inflation	52.43	35.82	11.74	54.82	33.01	12.17
Output	52.4	33.39	14.21	55.23	27.8	16.97
Nominal rate	22.27	69.06	8.67	96.45	1.74	1.81
Consumption	45.56	37.57	16.87	49.78	26.07	24.15
Investment	3.32	96.61	0.06	27.6	70.05	2.35
Loans	3.28	96.71	0.01	27.6	70.05	2.35
Hous. real price	60.92	29.64	9.43	61.44	27.75	10.81
Ent. loans	57.14	25.43	17.43	56.91	24.94	18.15
Imp. loans	30.17	68.51	1.32	84.9	15.04	0.06
Deposits	36.67	46.6	16.74	19.54	36.59	43.87
Imp. hous. demand	38.04	61.27	0.69	78.26	19.05	2.69
Banking capital	38.04	61.27	0.69	78.26	19.05	2.69
Banking profit	27.67	62.39	9.95	54.82	33.01	12.17
Ent. loan rate	37.37	52.96	9.68	52.88	42.13	5
Imp. loan rate	28.79	62.23	8.98	60.99	31.57	7.44
CAR	23.11	69.67	7.21	31.98	64.12	3.9
ROA	52.43	35.82	11.74	54.82	33.01	12.17
SR	52.4	33.39	14.21	55.23	27.8	16.97
Markup Loans Imp.	22.27	69.06	8.67	96.45	1.74	1.81
Markup Loans Ent.	45.56	37.57	16.87	49.78	26.07	24.15

Note: The real shocks are technology, price markup, preference, and investment shocks. Financial shocks are the deposit, loan markup, and LTV shocks.

Table 7: Variance Decompositions: CC

	Long run			Short run		
	Real	Financial	Interest Rate	Real	Financial	Interest Rate
Inflation	52.43	35.83	11.74	55	32.81	12.19
Output	53.14	32.97	13.89	56.46	26.85	16.69
Nominal rate	22	69.29	8.71	96.53	1.68	1.78
Consumption	45.56	37.99	16.45	50.58	25.39	24.03
Investment	3.5	96.45	0.05	27.31	70.65	2.04
Loans	3.56	96.43	0.01	27.31	70.65	2.04
Hous. real price	61.42	29.37	9.21	62.14	27.25	10.61
Ent. loans	58.92	23.9	17.18	58.76	23.34	17.89
Imp. loans	26.05	72.38	1.57	86.71	13.07	0.22
Deposits	35.18	48.44	16.38	18.38	38.97	42.65
Imp. hous. demand	32.01	67.41	0.58	80.15	17.32	2.53
Banking capital	32.01	67.41	0.58	80.15	17.32	2.53
Banking profit	28.9	60.98	10.12	55	32.81	12.19
Ent. loan rate	41.81	48.69	9.5	55.13	39.68	5.19
Imp. loan rate	32.16	59.01	8.83	64.2	28.57	7.22
CAR	24.57	68.69	6.74	32.19	64.19	3.62
ROA	52.43	35.83	11.74	55	32.81	12.19
SR	53.14	32.97	13.89	56.46	26.85	16.69
Markup Loans Imp.	22	69.29	8.71	96.53	1.68	1.78
Markup Loans Ent.	45.56	37.99	16.45	50.58	25.39	24.03

Note: The real shocks are technology, price markup, preference, and investment shocks. Financial shocks are the deposit, loan markup, and LTV shocks.

Table 8: Variance Decompositions: BC

	Long run			Short run		
	Real	Financial	Interest Rate	Real	Financial	Interest Rate
Inflation	51.7	36.75	11.55	54.17	33.84	11.99
Output	52.05	34.07	13.88	55.04	28.33	16.63
Nominal rate	21.84	69.62	8.54	96.42	1.79	1.79
Consumption	44.98	38.56	16.45	49.61	26.54	23.85
Investment	3.35	96.59	0.06	26.99	70.85	2.16
Loans	3.34	96.65	0.01	26.99	70.85	2.16
Hous. real price	60.42	30.38	9.2	60.97	28.47	10.56
Ent. loans	57.33	25.52	17.15	57.25	24.84	17.91
Imp. loans	25.8	72.91	1.29	84.56	15.34	0.11
Deposits	34.79	49.25	15.96	18.05	40.82	41.13
Imp. hous. demand	29.67	69.8	0.53	78.13	19.27	2.6
Banking capital	29.67	69.8	0.53	78.13	19.27	2.6
Banking profit	27.11	63.19	9.7	54.17	33.84	11.99
Ent. loan rate	37.83	52.81	9.36	51.13	44.08	4.79
Imp. loan rate	28.83	62.56	8.61	62.39	30.29	7.32
CAR	21.01	72.72	6.27	26.54	70.35	3.11
ROA	51.7	36.75	11.55	54.17	33.84	11.99
SR	52.05	34.07	13.88	55.04	28.33	16.63
Markup Loans Imp.	21.84	69.62	8.54	96.42	1.79	1.79
Markup Loans Ent.	44.98	38.56	16.45	49.61	26.54	23.85

Note: The real shocks are technology, price markup, preference, and investment shocks. Financial shocks comprise deposit,loan markup, and LTV shocks.