

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 reduce markups and foster riskier behavior, concentrated banking 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 amplifies the effects of the shocks relative to monopolistic competition. The transmission mechanism works through the markups, which are amplified when banking concentration is increased. The desirable banking market structure is determined according to financial stability and social welfare objectives. Depending on policymakers' preferences, banking concentration of five to eight banks balances social welfare and bank stability objectives in the US.

Keywords: Banking Concentration, Imperfect Competition, Financial Stability, Welfare Analysis, DSGE Model.

JEL Codes: D43, E43, E51, G21.

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1 Introduction

Banking competition became a key field of study in the aftermath of the global financial crisis (GFC) as political and economic policies, banking unions, and especially regulations transformed the banking market. A desirable banking market structure emerged as a central objective (Vives, 2016). Nevertheless, this structure is not established theoretically within the dynamic stochastic general equilibrium (DSGE) framework, which considers the combined effects of agents' welfare, financial stability, and macroeconomic dynamics.¹ This study addresses this gap by identifying the desirable number of banks that would improve financial stability and social welfare.

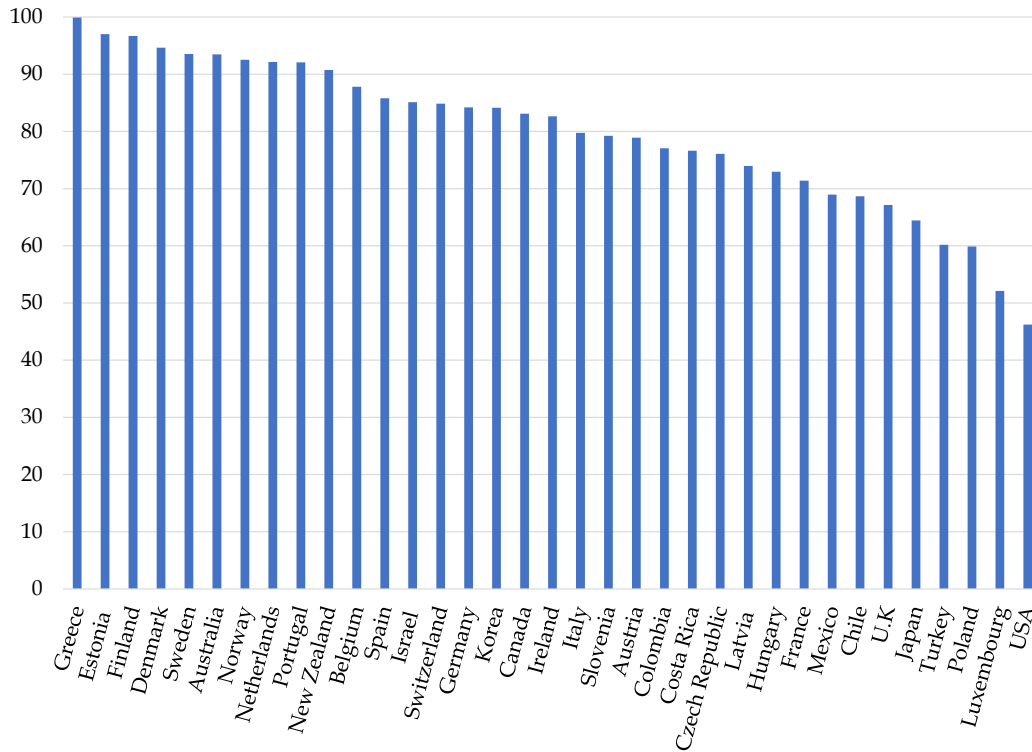
The relationship between bank competition and welfare, on the one hand, and financial stability on the other, is complex due to the intermediation role played by banks. First, the extent to which bank competition influences welfare may vary with the market size, institutional environment, and ownership structure of banking systems (Berger and Mester, 1997). Second, the literature provides two opposing views on the relationship between bank competition and financial stability (Allen and Gale, 2004a). On the one hand, bank 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, the *competition-stability* view 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, leading to riskier firm behavior. The expected rate of return on bank assets and the standard deviation of those returns would likely rise when bank concentration is positively correlated 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 various measures. For instance, the concentration ratio compares the total assets held by the N largest banks to the total assets held by commercial banks. For the five largest banks, the concentration ratio of the US banking market increased significantly from 30% in the early 2000s to 45% in 2017. (see Section 2). However, the US concentration ratio still remains below the OECD average (Fig. 1).

The issue of bank competition has been receiving increased attention for several reasons. First, in the aftermath of the GFC, regulated and concentrated banking markets appeared more resilient to crises. Australia and Canada are

¹While 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), 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.

Figure 1: Banking Concentration in the OECD



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

examples of countries where regulations on bank competition may have preserved financial stability during and after the GFC (Brown et al., 2017; U-Din et al., 2022). Their regulations prohibit mergers between the largest banks and maintain an oligopolistic and highly concentrated banking market structure.² Policymakers in Australia and Canada favor a banking sector with four and five dominant banks, respectively. Second, the issue of banking competition is central in Europe, particularly due to the ongoing debate regarding cross-border banking consolidation. This consolidation is viewed as both a means of financial integration and a way to reduce 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 is conducted using a nonlinear DSGE framework in which we incorporate various measures of financial stability and welfare. We formalize a policy frontier in which the policymaker obtains the desirable number of banks

²In these two countries, five banks hold more than 80% of the market shares of loans and deposits.

achieving maximum financial stability and welfare.

Our study is at the intersection of several strands of literature. First, our model enhances the consideration of the banking sector in DSGE models by introducing oligopolistic competition. Even when financial intermediaries are incorporated in the DSGE literature, these models disregard their role by assuming PC, despite empirical and theoretical evidence suggesting that banks compete imperfectly (Kiyotaki and Moore, 1997; Bernanke et al., 1999; Iacoviello, 2005). Under this framework, accurately assessing the effects of financial sector shocks on economic variables is problematic due to the assumption that private banks have no market power and, consequently, no influence on interest rate settings. Although the literature on banking has grown significantly since the GFC (Meh and Moran, 2010; Kollmann et al., 2011; Angeloni and Faia, 2013; Brunnermeier and Sannikov, 2014), the crucial characteristics of the banking sector have not been adequately investigated. Some models incorporate the financial sector as a technical feature (Iacoviello, 2015), while others consider financial shocks without accounting for 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) significantly contribute to the literature. Market power has become an essential element in setting interest rates (Gerali et al., 2010; Darracq Pariès et al., 2011; Brzoza-Brzezina et al., 2013). Although MC confers a specific market power to banks, it does not consider certain characteristics of the banking sector, such as the limited number of banks, strategic interactions, and barriers to entry. Therefore, oligopolistic competition should better capture most banking market characteristics. This study introduces an oligopolistic framework that addresses some of these shortcomings. Second, we consider the number of banks as a determinant of markups, contributing to the literature on the relationships between bank competition, concentration, 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 substitutable³ and ignore service quality.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 (MC, CC, and BC). The first cat-

³Considering 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.

⁴Dick (2007) suggest that there is a lower bound to concentration in the banking industry, which converges to a positive value as market size increases. This market structure is sustained by investments in service quality that increase with the market size. The market is asymmetric, with a few dominant banks that are large and geographically diversified and a fringe of small, local banks. The number of dominant banks remains constant across markets of different sizes, while the number of fringe competitors varies. Dominant banks offer higher quality services than fringe banks, with larger branch networks, bigger staff, and higher salaries. Dominant banks focus more on retail and providing credit lines for financing on demand, while fringe banks focus more on small business customers. Dick (2007) find that dominant banks use quality investments to capture additional demand when the market size expands, raising barriers to entry.

egory of results compares different banking market structures, introducing the number of banks (N) as a determinant of markups, which modifies the dynamics of interest rate setting. 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.

The second category of results stems from the formalization of the policy frontier. This approach enables us to represent the trade-off the central bank faces in determining the desirable number of banks. The two objectives considered are financial stability and welfare, which move in opposite directions with respect to market concentration. An increase in the number of banks alters banks' markup, affecting financial stability. This negative relationship is related to the *competition-fragility* view. However, increasing the number of banks improves households' and entrepreneurs' welfare. Therefore, an oligopolistic market structure with fewer banks is less desirable for agents than a competitive market structure with more banks. We find that the trade-off between financial stability and welfare should lead policymakers to limit the number of banks to around 4 to 6 banks in the US. This 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. Section 2 presents our models of imperfect competition. 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 effect of competition on both social welfare and financial stability and the trade-off between those variables. Section 7 interprets the results and draws policy implications, and Section 8 concludes the study.

2 Imperfect Competition

Our models extend Gerali et al. (2010) by adding alternative banking competition structures. In Gerali et al. (2010), banks' market power was introduced through MC at the retail level. This implies that an infinite number of banks obtain market power by differentiating their supply, an assumption that seems unrealistic when we examine the evolution of the concentration ratio of the US banking market (Fig. 2). The US banking market is concentrated with five banks holding 50% of the market.⁵

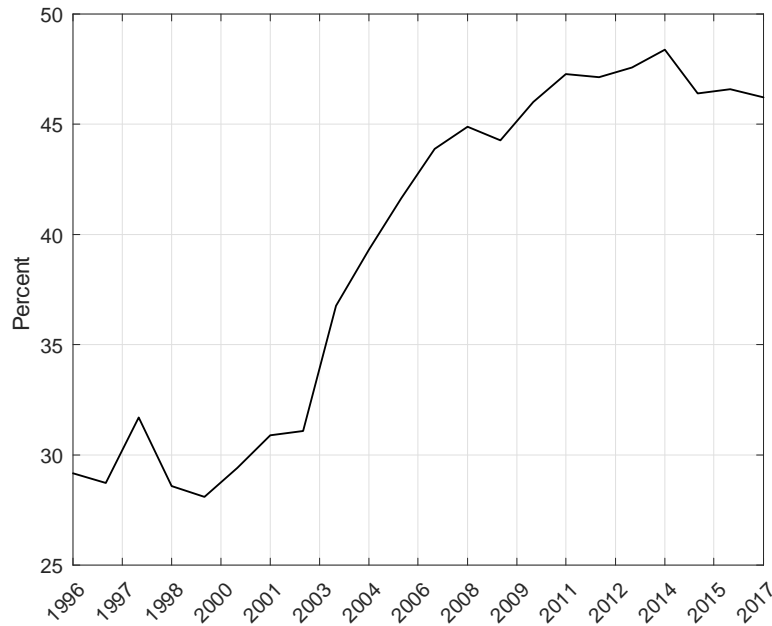
Fig. 2 highlights two waves of concentration: the first in 2004 and the second in 2008. In 1997, the five largest banks held 30% of total bank assets, which increased to approximately 50% after the GFC.⁶

Regulations in a few countries favor an oligopolistic banking market framework, arguing that it would be a source of greater financial stability. From this

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

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

Figure 2: Banking Concentration in the US



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

perspective, we added two alternative competition structures to the Gerali et al. (2010) model, Cournot and Bertrand oligopolies (CC and BC). The oligopolistic framework allows us to introduce the number of banks (as a proxy of concentration) in analyzing the behavior of setting interest rates on loans. 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 impacts the 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

⁷Few have quantified the banks' ability to set prices above the marginal costs of different

The rest of our model aligns with Gerali et al. (2010) regarding the proposed modeling hypotheses. We present the details of the model in 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 to 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, crucial for determining the entrepreneurs' collateral value. We also consider the nominal rigidities, essential for matching empirical data, by adding retailers (Section A.4). They 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 as in Rotemberg (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), where each bank $j \in [0, 1]$ in the model comprises two retail branches and one wholesale branch (Section 2.5). 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 that depends on the banking market structure (MC, CC, and BC presented in Sections 2.5.1, 2.5.2, and 2.5.3, respectively).

2.1 Wholesale Branch

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

$$K_{b,t} + D_t = B_t, \quad (1)$$

where $K_{b,t}$ (bank capital) and D_t (total deposits) corresponds to liabilities and $B_t = b_{i,t} + b_{e,t}$ (sum of impatient and entrepreneur loans) to assets. Bank capital follows the standard capital accumulation equation

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

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.

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).

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

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

under the balance sheet condition (Eq. 1). The bank incurs a quadratic cost κ_{kb} when the capital adequacy 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 condition (Eq. 1) into the wholesale branch optimization problem, we obtain the following simplified equations to maximize:

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

The optimality condition is:

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

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

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

The aggregate profit of all the banks is

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

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 the deposit rate (κ_d) and the quadratic cost observed when the capital adequacy ratio deviates from the target value (κ_{kb}).

2.2 Deposit Demand

Deposit demand from agents is not subject to different types of competition.⁸

Banks raise deposits from an infinite number of differentiated depositors. The demand for deposits is aggregated through a CES aggregator. The demand for

⁸Unlike Egan et al. (2017), we assume that banks receive deposits passively and the market structure does not influence the shape of the deposit demand function.

household deposits i is obtained by maximizing the revenue of total savings obtained from the continuum of bank j , such that

$$\int_0^1 R_t^d(j) d_t(i, j) dj, \quad (8)$$

subject to

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

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

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

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 the economy-wide demand for deposits. $\varsigma_{d,t}$ is the exogenous elasticity of deposit substitution, detailed in Section 2.8.

2.3 Loan Demand

We express the loan demand function for each type of competition.

2.3.1 Monopolistic Competition

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

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

$$\int_0^1 R_t^{b_k}(j) b_{k,t}(i, j) dj, \quad (11)$$

subject to

$$\left[\int_0^1 b_{k,t}(i, j)^{\frac{\varsigma_{bk,t}-1}{\varsigma_{bk,t}}} dj \right]^{\frac{\varsigma_{bk,t}}{\varsigma_{bk,t}-1}}. \quad (12)$$

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

$$b_{k,t}(j) = \left(\frac{R_t^{b_k}(j)}{R_t^{b_k}} \right)^{-\varsigma_{bk,t}} b_{k,t}, \quad (13)$$

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 loans. $\varsigma_{b,k,t}$ denotes the exogenous elasticity of loan substitutability detailed in section 2.8.

2.3.2 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 obtain the inverse demand function presented in Colciago and Etro (2010).

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

$$q_{bk,t} = \sum_{i=1}^N R_t^{b_k}(i) b_{k,t}(i) = R_t^{b_k} b_{k,t}. \quad (14)$$

From the CES demand function of loans (Eq. 13), we have

$$b_{k,t}(j) = \left(\frac{R_t^{b_k}(j)}{R_t^{b_k}} \right)^{-\varsigma_{bk,t}} b_{k,t} = \frac{R_t^{b_k}(j)^{-\varsigma_{bk,t}}}{R_t^{b_k^{1-\varsigma_{bk,t}}}} R_t^{b_k} b_{k,t}. \quad (15)$$

As we have $q_{bk,t} = R_t^{b_k} b_{k,t}$,

$$b_{k,t}(j) = \frac{R_t^{b_k}(j)^{-\varsigma_{bk,t}}}{R_t^{b_k^{1-\varsigma_{bk,t}}}} q_{bk,t}. \quad (16)$$

After inverting the direct function of demand, we obtain the following equation

$$R_t^{b_k}(j) = \frac{b_{k,t}(j)^{-\frac{1}{\varsigma_{bk,t}}}}{q_{bk,t}^{-\frac{1}{\varsigma_{bk,t}}}} R_t^{b_k^{\frac{\varsigma_{bk,t}-1}{\varsigma_{bk,t}}}}. \quad (17)$$

We plug Eq. 14 into Eq. 17 to obtain

$$R_t^{b_k}(j) = \frac{b_{k,t}(j)^{-\frac{1}{\varsigma_{bk,t}}}}{b_{k,t}^{\frac{\varsigma_{bk,t}-1}{\varsigma_{bk,t}}}} q_{bk,t}. \quad (18)$$

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

$$R_t^{b_k}(j) = \frac{b_{k,t}(j)^{-\frac{1}{\varsigma_{bk,t}}}}{\sum_{i=1}^N b_{k,t}(i)^{\frac{\varsigma_{bk,t}-1}{\varsigma_{bk,t}}}} q_{bk,t}. \quad (19)$$

2.3.3 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 CES demand function of loans (Eq. 13), we have

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

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

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

where

$$R_t^{b_k} = \left[\sum_{i=1}^N R_t^{b_k}(i)^{-(\varsigma_{bk,t}-1)} \right]^{-\frac{1}{\varsigma_{bk,t}-1}}. \quad (22)$$

We plug Eq. 22 into Eq. 21 to obtain the direct demand function of deposit with strategic interactions

$$b_{k,t}(j) = \frac{R_t^{b_k}(j)^{-\varsigma_{bk,t}}}{\sum_{i=1}^N R_t^{b_k}(i)^{-(\varsigma_{bk,t}-1)}} q_{bk,t}. \quad (23)$$

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

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

2.4 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

$$\mathbb{E}_t \sum_{t=0}^{\infty} \Lambda_{t,t+k}^b \left[\left(R_t - R_t^d(j) \right) d_t(j) \right], \quad (25)$$

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

$$R_t^d = R_t \frac{\varsigma_{d,t}}{\varsigma_{d,t} - 1}. \quad (26)$$

2.5 Retail Loan Branch

The loan branch grants loans to impatient households and entrepreneurs.

The retail loan bank maximizes the profit function

$$\mathbb{E}_t \sum_{t=0}^{\infty} \Lambda_{t,t+k}^b \left[\sum_{k=e,i} R_t^{b_k}(j) b_{k,t}(j) - R_{b,t}(j) \left(\sum_{k=e,i} b_{k,t}(j) \right) \right], \quad (27)$$

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 maximization program of the loan branch for each competition type.

2.5.1 Monopolistic Competition

This section details the loan bank's maximization program under monopolistic competition. Each bank j chooses the rate $R_t^{b_k}(j)$ that maximizes the equation of the profits given by Eq. 27 under the CES demand function of loans, given by Eq. 13.

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

$$R_t^{b_k} = R_{b,t} \frac{\varsigma_{b_k,t}}{\varsigma_{b_k,t} - 1}, \quad (28)$$

The loan markup equilibrium is

$$\mu_{b_k,t}^{MC} = \frac{\varsigma_{b_k,t}}{\varsigma_{b_k,t} - 1}. \quad (29)$$

Finally, the markup depends on the time-varying intertemporal elasticity of loan substitutability. The markup decreases with the degree of loan substitutability.

2.5.2 Cournot Competition

This section details the loan bank's maximization program under CC. As banks compete on quantities, bank j chooses the loan amount $b_{k,t}$ that maximizes profits, which is given by Eq. 27, taking the production of all banks and the inverse function of demand as given (Eq. 19).

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

$$R_{b,t} = \left(\frac{\varsigma_{b_{k,t}} - 1}{\varsigma_{b_{k,t}}} \right) \frac{b_{k,t}(j)^{\frac{-1}{\varsigma_{b_{k,t}}}} q_{b_{k,t}}}{\sum_{i=1}^{N_t} b_{k,t}(i)^{\frac{\varsigma_{b_{k,t}}-1}{\varsigma_{b_{k,t}}}}} - \left(\frac{\varsigma_{b_{k,t}} - 1}{\varsigma_{b_{k,t}}} \right) \frac{b_{k,t}(j)^{\frac{\varsigma_{b_{k,t}}-2}{\varsigma_{b_{k,t}}}} q_{b_{k,t}}}{\left(\sum_{j=i}^{N_t} b_{k,t}(i)^{\frac{\varsigma_{b_{k,t}}-1}{\varsigma_{b_{k,t}}}} \right)^2}. \quad (30)$$

N banks compete on quantity for each period, choosing their individual supply $b_{k,t}(j)$ that maximizes profits by taking all other banks' supply as given. For all banks $j \in \{1, 2, \dots, N\}$, Eq. 30 can be simplified by imposing a symmetric equilibrium.

This generates a symmetric individual loan supply

$$b_{k,t} = \frac{(\varsigma_{b_{k,t}} - 1)(N - 1) q_{b_{k,t}}}{R_{b,t} \varsigma_{b_{k,t}} N^2}, \quad (31)$$

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

$$R_t^{b_k} = R_{b,t} \frac{N}{N - 1} \frac{\varsigma_{b_{k,t}}}{\varsigma_{b_{k,t}} - 1} \quad (32)$$

The loan markup equilibrium is

$$\mu_{b_{k,t}}^C = \frac{\varsigma_{b_{k,t}} N}{(\varsigma_{b_{k,t}} - 1)(N - 1)}. \quad (33)$$

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 $\xi_{\varsigma_{b_{k,t}}}^C = 1/(\varsigma_{b_{k,t}} - 1)$ and remains positive for any degree of substitutability, even for homogeneous loans ($\lim_{\varsigma_{b_{k,t}} \rightarrow +\infty} \mu_{b_{k,t}}^C = N/(N - 1)$). 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 $\lim_{N \rightarrow +\infty} \mu_{b_{k,t}}^C = \varsigma_{b_{k,t}}/(\varsigma_{b_{k,t}} - 1) > 1$, for any degree of substitutability. Thus, when the number of banks tends to be infinite, we find the case of MC. Its elasticity $\xi_N^C = 1/(1 - N)$ decreases with the number of banks and is independent of the degree of substitutability between loans.

2.5.3 Bertrand Competition

This section details the loan bank's maximization program under BC. As banks compete in prices, each bank j chooses rate $R_t^{b_k}(j)$ that maximizes profits given

by Eq. 27 by assuming that the rate of other banks i and the demand function of loans with strategic interactions, as shown by Eq. 24, are given.

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

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

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

$$R_t^{bk} = R_{b,t} \frac{\varsigma_{bk,t} (1-N) - 1}{(1-\varsigma_{bk,t})(N-1)}, \quad (35)$$

which is associated with the following equilibrium markup

$$\mu_{d,t}^B = \frac{\varsigma_{bk,t} (1-N) - 1}{(1-\varsigma_{bk,t})(N-1)}. \quad (36)$$

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 $\varsigma_{bk,t}$ with elasticity

$$\tilde{\varsigma}_{k,t}^B = \frac{\varsigma_{bk,t} N}{(\varsigma_{bk,t}-1)(1-\varsigma_{bk,t} + \varsigma_{bk,t} N)}, \quad (37)$$

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 $\lim_{\varsigma_{bk,t} \rightarrow \infty} \mu_{d,t} = 1$. This indicates that banks cannot generate higher markups under PC when loans are perfectly substitutable. This is known as the *Bertrand paradox*.

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

$$\tilde{\varsigma}_N^B = \frac{N}{(N-1)(1 + \varsigma_{bk,t}(N-1))} \quad (38)$$

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 competition 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 ($\varsigma_{b,t}$), and depend on the number of banks (N), making the model steady-state dependent on N . See Appendix C for more details.

2.6 Financial Stability

Banking regulations, specifically capital requirements implemented under the Basel III accords, highlight the role of bank liquidity in the absorption of financial shocks by the banking sector. Therefore, well-capitalized banks are essential in ensuring financial stability. Our model allowed us to simulate three indicators of bank liquidity: capital adequacy ratio (CAR), Z-Score (ZS), and Solvency Ratio (SR). The CAR assesses the capital requirement that ensures stability for the banking system (Goodhart et al., 2004). The ZS is inversely related to the probability of bank insolvency and is also used in empirical models (Boyd and Runkle, 1993; Laeven and Levine, 2009) to measure the distance from insolvency (Roy, 1952), where insolvency is defined as a state in which losses exceed equity. The SR measures bank insolvency risk and its relationship to the probability of a financial institution's insolvency, which is also used in the literature to assess bank insolvency risk that could require regulatory intervention (Chernykh and Cole, 2015).

CAR measures the bank's capital, expressed as a percentage of loan exposure, such that

$$CAR_t = \frac{K_{b,t}}{B_t}, \quad (39)$$

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

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

where $ROA_t = J_{b,t}/B_t$ is the return on assets, $J_{b,t}$ is the net bank profits and $\sigma(\cdot)$ is the standard deviation operator. The aggregate ZS measures the probability of default of the banking system.

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

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

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

2.7 Welfare Analysis

From a normative perspective, we aim to determine the socially desirable number of banks for households (patient and impatient) and entrepreneurs. Our welfare measure is based on the discounted lifetime utility of households and entrepreneurs (Garín et al., 2016), a common approach in financial stability models (Rubio and Carrasco-Gallego, 2014).

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

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

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 β_{\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 following Garín et al. (2016) such that:

$$CEV_{\varkappa,t} = 100 \times [\exp(W_{\varkappa,t}^* - W_{\varkappa,t}) - 1], \quad (43)$$

where the benchmark model represents the economy without banks' market power, such as under PC. We can interpret this compensating variation as a measure of welfare loss due to the competition and concentration states. Therefore, more desirable states coincide with lower compensating variation values (See Fig. 12).

The total welfare is calculated in two steps : first, by aggregating the welfare of patient and impatient households, and then by adding the welfare of entrepreneurs.

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

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

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

Our welfare analysis aims to identify the socially optimal choice of the banking concentration system. We determine the number of banks that maximizes the total social welfare in the economy represented as the average⁹ of $CEV_{h,t}$ and

⁹ Alternative configurations and weightings are available upon request.

$CEV_{e,t}$. Since increasing the number of banks increases the welfare of both classes of agents, maximizing the weighted sum of households and entrepreneurs' welfare may not generate outcomes that worsen one of the groups' situations relative to the other.

2.8 Stochastic Structure

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

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

where $X_t \in \{\varsigma_{d,t}, \varsigma_{b_{k,t}}\}$, \bar{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 detailed in Appendix A.8.

3 Calibration

Our parameters are calibrated according to the literature and historical steady-state ratios in the US.¹⁰ 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,¹¹ 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 ν is calibrated to 0.2, which is close to the calculated ratio of US residential investment to GDP. The inverse of Frisch elasticity (φ) is calibrated to one as in Galí (2008). Capital share in the production function α is 0.25, and the depreciation rate of capital δ_k is 0.03 following Brzoza-Brzezina et al. (2013). The share of patient households μ is calibrated to 0.8, aligning with Iacoviello and Neri (2010). The steady-state price markup $\bar{\epsilon}$ is calibrated to 11, leading to a price markup of 1.1%, a common value in literature (Galí, 2008). The impatient households' LTV ratio, $\bar{m}_{i,t}$ is set to 0.7, reflecting the US share of housing loans to GDP, similar to Iacoviello (2005). The entrepreneur's LTV ratio, $\bar{m}_{e,t}$ is 0.25, reflecting the evidence that entrepreneurs cannot collateralize their loans as easily as impatient households.

¹⁰We calibrate our model from quarterly US data. We made this choice owing to 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.

¹¹In the steady-state, borrowing constraints bind if and only if the Lagrange multipliers (λ_i and λ_e) are greater than 0. As $\lambda_i = \frac{1}{c_i} (\beta_p - \beta_i)$ and $\lambda_e = \frac{1}{c_e} (\beta_p - \beta_e)$, 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 over precautionary savings.

Table 1: Definition and calibration of models' parameters.

<i>Parameter</i>	<i>Description</i>	<i>Calibration</i>
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
ν	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
ι_p	Price stickiness index to past inflation	0.15
v	Bank capital regulation	0.11
ϕ_π	Weight of inflation in the monetary policy rule	2.5
ϕ_Y	Weight of output gap in the monetary policy rule	0.1
ρ_R	Interest rate smoothing	0.8
κ_d	Deposit rate adjustment cost	10
κ_i	Investment change adjustment cost	10
κ_p	Price adjustment cost	33
κ_{kb}	Capital adequacy ratio deviation to target cost	50
$\bar{\epsilon}$	Steady-state price markup	11
$\bar{\varsigma}_d$	Steady-state elasticity of substitution of deposits	-1.02
$\bar{\varsigma}_{bi}$	Steady-state elasticity of substitution of impatient loans	2.95
$\bar{\varsigma}_{be}$	Steady-state elasticity of substitution of entrepreneur loans	2.6
$\bar{m}_{i,t}$	Steady-state LTV ratio of impatient households	0.7
$\bar{m}_{e,t}$	Steady-state LTV ratio of impatient entrepreneurs	0.25

For banking parameters, only a few studies estimate the value for the US. The elasticity of substitution for deposits $\bar{\varsigma}_d$ is -1.02, a value in line with a Federal Reserve interest rate equal to 1.20%. The elasticity of substitution for loans to impatient households $\bar{\varsigma}_{bi}$ and entrepreneurs $\bar{\varsigma}_{be}$ are calibrated to 2.95 and 2.6, respectively. These values reflect the average monthly spread between the loan rate to impatient households and firms and the monetary policy rate¹². Considering the recent condition of US commercial bank balance sheets, we calibrate bank capital regulation v to 0.11. The steady-state gross inflation rate $\bar{\pi}$, output \bar{Y} and capital price \bar{q}_k equal one, similar to the steady-state value of the monetary policy shock $\bar{\epsilon}_r$, investment goods productivity shock $\bar{\epsilon}_{qk}$, and preference shock

¹²The calibration of the banking sector parameters involves calculating the difference between the average bank rate (household and corporate) and the monetary policy rate. This difference reflects the banks' market power. Given our different structural models, the calibrated value under oligopoly should vary according to the value of N . For simplicity, we keep this value constant. An 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 settings when markups consider different market structures.

ϵ_z .

4 Moment Matching

Our calibration procedure follows Christiano et al. (2010). Table 2 presents parameters and shock variances of stochastic processes chosen to align with the first and second-order moments of the data presented in Appendix D.

Table 2: Definition and calibration of shock processes' parameters.

<i>Parameter</i>	<i>Description</i>	<i>Calibration</i>
ρ_{A_e}	Technology shock persistence	0.92
ρ_{m_i}	Impatient LTV shock persistence	0.20
ρ_{m_e}	Entrepreneur LTV shock persistence	0.30
ρ_{ϵ}	Price markup shock persistence	0.50
$\rho_{\epsilon_{qk}}$	Investment goods productivity shock persistence	0.80
ρ_{ϵ_z}	Preference shock persistence	0.60
ρ_{ϵ_r}	Monetary policy shock persistence	0.10
ρ_{ζ_d}	Deposit markup shock persistence	0.95
$\rho_{\zeta_{b_i}}$	Impatient loan markup shock persistence	0.90
$\rho_{\zeta_{b_e}}$	Entrepreneur loan markup shock persistence	0.90
σ_{A_e}	Technology shock standard error	0.001
σ_{m_i}	Impatient LTV shock standard error	0.001
σ_{m_e}	Entrepreneur LTV shock standard error	0.001
σ_{ϵ}	Price markup shock standard error	1.010
$\sigma_{\epsilon_{qk}}$	Investment goods productivity shock standard error	0.011
σ_{ϵ_z}	Preference shock standard error	0.004
σ_{ϵ_r}	Monetary policy shock standard error	0.001
σ_{ζ_d}	Deposit markup shock standard error	0.010
$\sigma_{\zeta_{b_i}}$	Impatient loan markup shock standard error	0.100
$\sigma_{\zeta_{b_e}}$	Entrepreneur loan markup shock standard error	0.005

Since banks are assumed to be symmetric in our model, the 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.

Table 3 presents the steady-state ratio to output averages simulated from our models calibrated according to Table 1. We compare these theoretical averages with the historical US data.¹³ The simulations are conducted at a first-order approximation.

Table 3 shows that our models replicate averages of most historical variables within the confidence interval. Our models successfully capture key moments

¹³See Appendix D for more details on the data.

Table 3: Moment Matching - First Order

	MC	Averages			Confidence	
		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

Notes: Historical moments (Hist.) are calculated using data from 1975 to 2020. The averages represent the corresponding variable's steady-state ratios to the output. These results are obtained by assuming a banking system with four banks. Changing the number of banks does not significantly affect the main results. A 5% confidence interval is used across our 180 observations for each time series, assuming a normal distribution.

highlighted in the literature, along with additional moments such as bank profits, impatient households and entrepreneur loan rates. However, labor averages are not well replicated, primarily due to the simplified labor market modeling (e.g., wage rigidities are ignored).

Table 4 presents the simulated standard deviations and correlations for each competitive market structure based on calibrations presented in Table 1.

Comparing the simulated moments from Table 4 with the historical US data, we find that our models align with historical dynamics, except for the moments of a few variables, which are not accurately replicated. This discrepancy arises because the models are built to describe general economic and financial dynamics rather than being explicitly tailored to crises or volatile dynamics. Consequently, our models cannot fully reflect the volatility of bank capital and profits observed during the GFC and other crises over the past fifty five years.

5 Simulations

In this section, we examine the economy's response to real and financial shocks under MC, BC, and CC. We assume the same degree of loan substitutability across each model to allow comparison of competition types, maintaining a con-

Table 4: 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

Notes: Historical moments (Hist.) are calculated using data from 1975 to 2020. The calculated correlations represent the strength and direction of the relationship between each variable and the output. These results are obtained by assuming a banking system with four banks. Changing the number of banks does not significantly affect the main results.

sistent number of four banks to align with the typical banking market structure of most industrialized countries.¹⁴ This choice ensures that the banking industry is modeled as a concentrated market without falling into monopoly. We then examine the transmission of financial shocks under oligopoly following various banking market concentration scenarios (i.e., different values of N).

The impulse response functions are obtained by solving the nonlinear model at the second order approximation, and using an analytical steady-state. These impulse response functions are reported as percentage deviations from each variable's steady state.

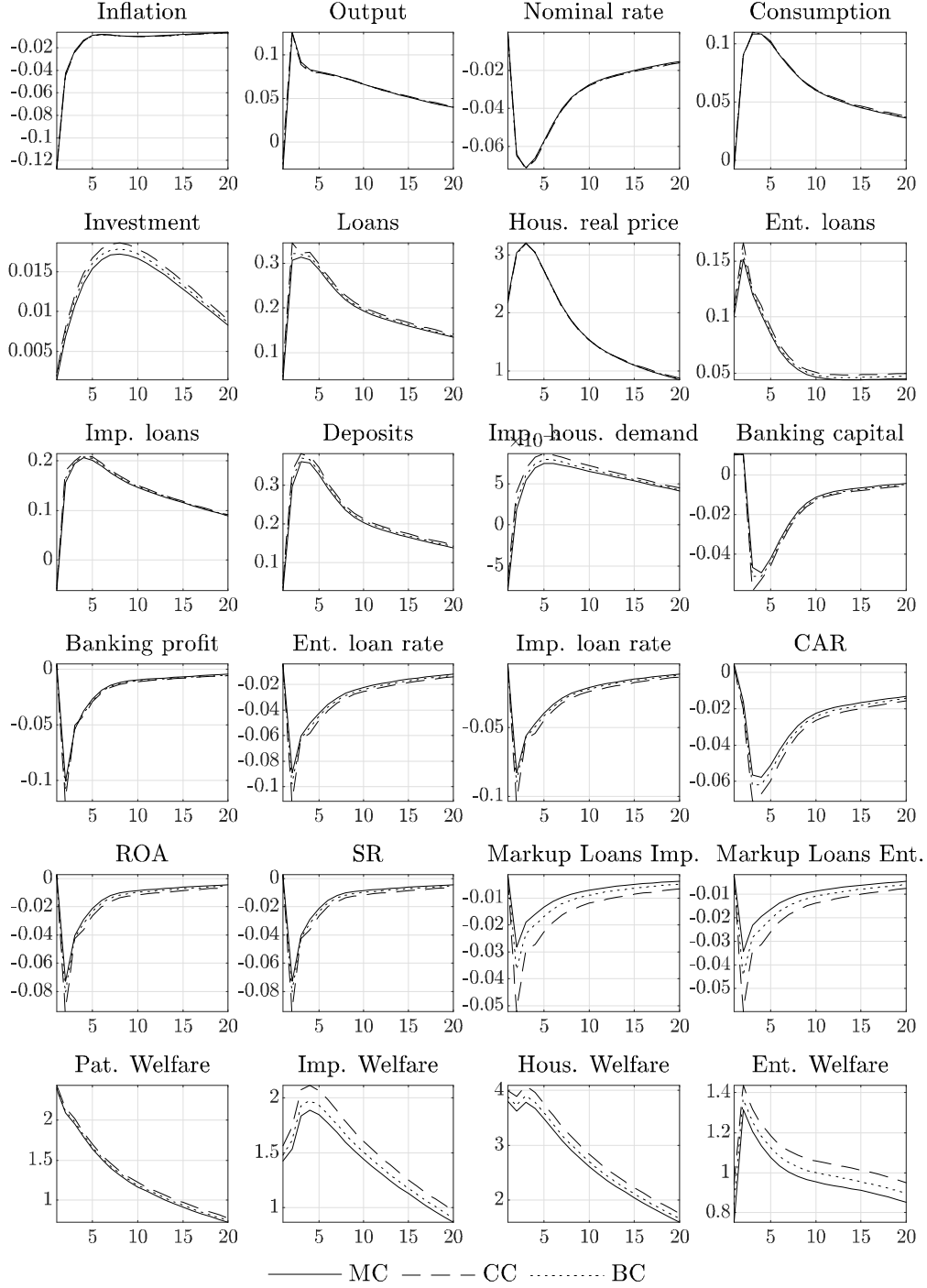
5.1 Technology and Competition

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

The results demonstrate that the transmission mechanism of a technology shock in the banking sector is fairly standard whatever competitive market structures. After the shock, firms increase their production (Fig. 3). Additional profits are obtained by patient households that consume an increasing amount of leisure time. Impatient households also benefit from higher wages, which allows them to consume more. In addition, the monetary authority lowers the policy rate as

¹⁴Impulse response functions for highly concentrated markets with two banks to less concentrated markets (up to 20 banks) and for different competition market structures (MC, BC, CC, and PC) are available upon request.

Figure 3: Response to a 1% technology shock



Notes: This figure depicts the impulse response functions of model variables to a 1% exogenous technology shock. The y-axis measures the percentage point change from the initial state, while the x-axis represents the number of quarters after the shock.

inflation declines. This is transmitted to retail rates, allowing entrepreneurs and households to benefit from better loan terms, increasing investment and housing demand.

Consistent with theoretical analysis, under imperfect competition, the rate set by banks is higher than the monetary policy rate due to market power (Gerali et al., 2010).

Among imperfect competition scenarios, banks generate lower markups in an oligopolistic market structure than MC. Furthermore, markups deteriorate more when banks compete on quantities (CC) rather than rates (BC), such that $\mu_{bk,t}^{MC} < \mu_{bk,t}^B < \mu_{bk,t}^C$. This finding aligns with the calculation of the markup elasticity in relation to the number of banks. Regardless of the concentration of the banking sector, elasticity under CC is greater than that under BC. Thus, the banking market structure modifies technology shock transmission through the markup channel.

The impact on markups leads to proportional reactions in other variables. Bank interest rates decline more sharply in oligopolistic markets, leading to a stronger increase in loans, especially when banks compete on quantity (CC). The same pattern holds for investment and housing responses. Moreover, bank liquidity suffers when markups decrease, particularly in oligopolies. Finally, the increase in unconditional household and entrepreneurial welfare, resulting from the decrease in bank markups, is more significant under CC than under BC or MC.¹⁵

5.2 Monetary Policy and Competition

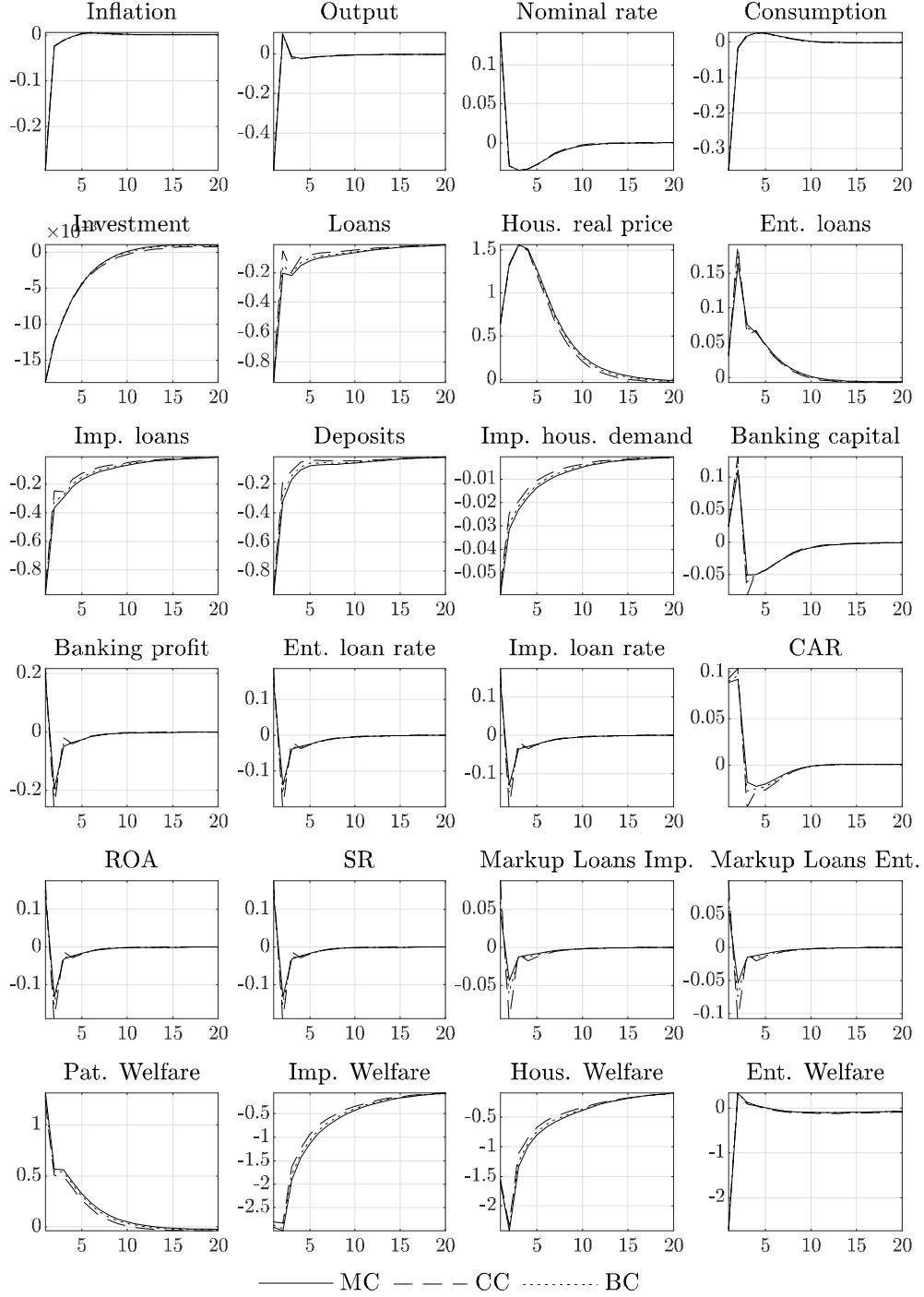
The transmission mechanism of monetary policy shocks to the economy is standard. As in Gerali et al. (2010), monetary policy is transmitted through the real rate, financial accelerator, and nominal debt effects (Fig. 4).

An increase in the monetary policy rate typically leads to higher real rates due to sticky prices in the economy. This triggers several effects on consumption, debt, and investment. Households, facing higher real rates, may choose to postpone consumption to benefit from future higher purchasing power. The "nominal debt effect" comes into play as prices decrease, raising the real cost of existing debt. This incentivizes borrowers to deleverage thereby reducing loan demand, resulting in an impact to investment and impatient households' housing demand. Moreover, the "financial accelerator effect" operates through collateral value. The rate increase typically reduces collateral value, prompting banks to restrict loan granting, further affecting investment and impatient households' housing demand.

The extent to which these changes occur depends on the competitive market structure. A monetary policy shock influences the process by which retail loan banks set interest rates. Since the policy rate directly affects the marginal cost of producing loans, an increase in the policy rate translates to a higher marginal

¹⁵The welfare presented in Section 5 (Figs. 3 to 10) is the unconditional welfare, $W_{\mathcal{X},t}$ explained by Eq. 42. The welfare analysis in compensating variation terms (Eq. 44) is presented in Section 6.

Figure 4: Response to a 1% monetary policy shock



Notes: This figure illustrates the impulse response functions of model variables to a 1% exogenous monetary policy shock. The y-axis measures the percentage point change from the initial state, while the x-axis represents the number of quarters after the shock.

cost.¹⁶ Oligopolistic banks choose a higher interest rate than MC for generating higher markups,¹⁷ given banks' market shares (ϵ_{bk}). Thus, given N and ϵ_{bk} , a change in R leads to a change in R^k , such that $R_{mc}^k < R_{bc}^k < R_{cc}^k$. The structure for loan responses remains consistent.

5.3 Loan Substitutability and Competition

This section analyzes financial shocks. Among possible financial shocks, we investigate a shock to the degree of loan substitutability for impatient households (ζ_{bi}) and entrepreneurs (ζ_{be}). This is equivalent to considering shocks to bank markups, since we have shown that bank markups depend on the number of banks in the economy (N) and the elasticity of loan substitutability. In this section, we only focus on loan substitutability, and the number of banks remains fixed.¹⁸

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

A shock to the degree of loan substitutability leads to an increase in markups, typically associated with credit crunch scenarios. Literature indicates that a positive shock to the loan markup leads to higher interest rates on related loans, resulting in lower loan amounts. We analyze the impact of such a shock on the loan rates of impatient households and entrepreneurs.

A loan markup shock for impatient households (Fig. 5) raises the loan rate, resulting in a decrease in the number of loans taken out by such households, which in turn lead to a decline in housing demand. Similarly, a loan markup shock for entrepreneurs (Fig. 6) increases their loan rate, thereby reducing the number of loans they obtain, lowering investment. This fall in investment corresponds to a decrease in aggregate demand, ultimately leading to a decline in output.

The degree to which housing demand and investment decline depends on the structure of the banking market because these shocks affect interest rate setting dynamics through changes in bank markups.

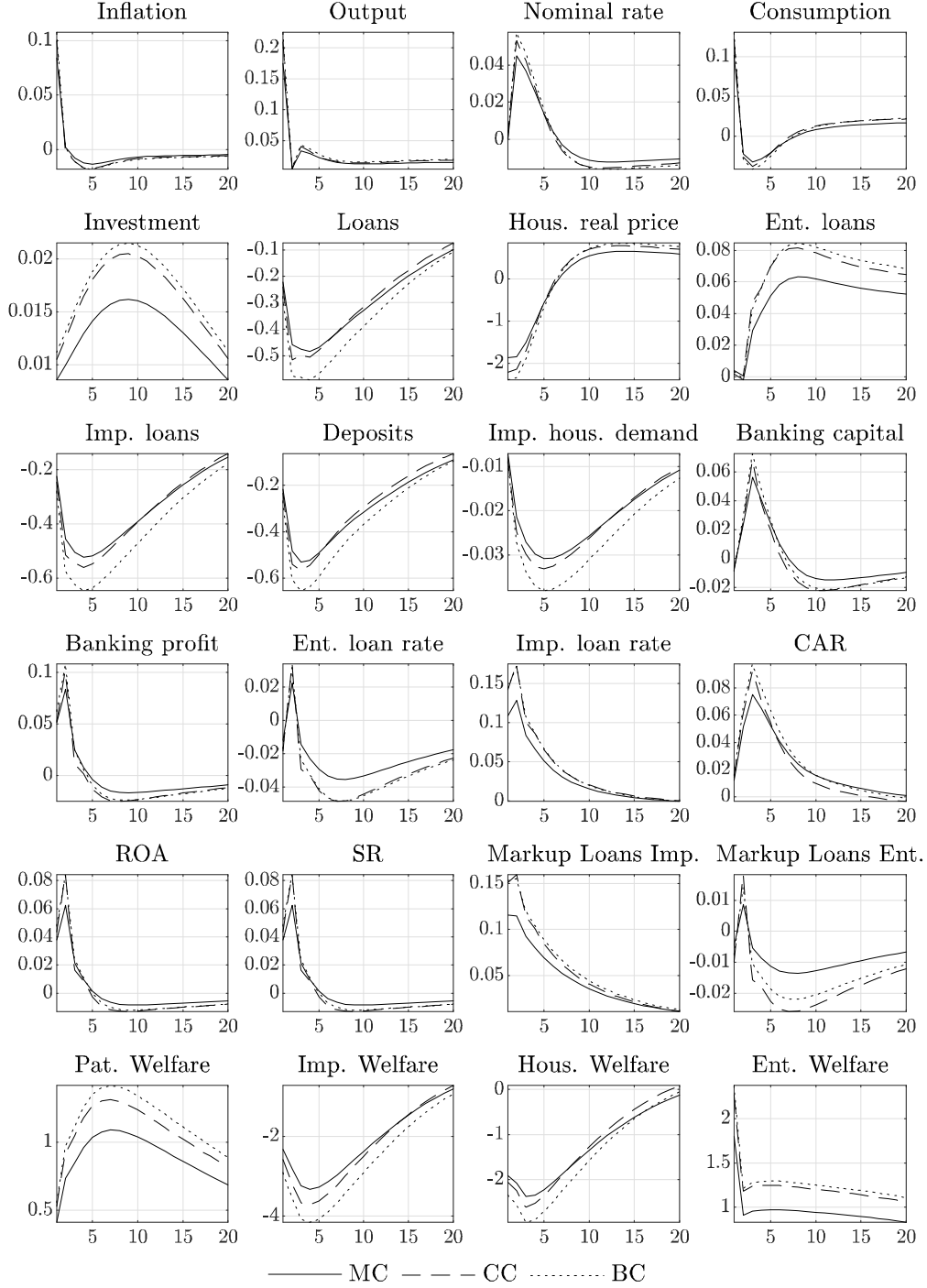
Markups are more sensitive to the degree of loan substitutability in oligopoly than in MC. Moreover, the elasticity of markup to the loan substitutability level is higher in BC than in CC, such that an increase in the degree of substitutability

¹⁶This increased cost is a positive factor in each equation used to determine the interest rate (Eq. 28, Eq. 32 and Eq. 35)

¹⁷The number of banks was fixed at 4 in our analysis. The more there are banks in a market, the closer oligopolistic competition becomes to the MC case, where banks have negligible influence on each other.

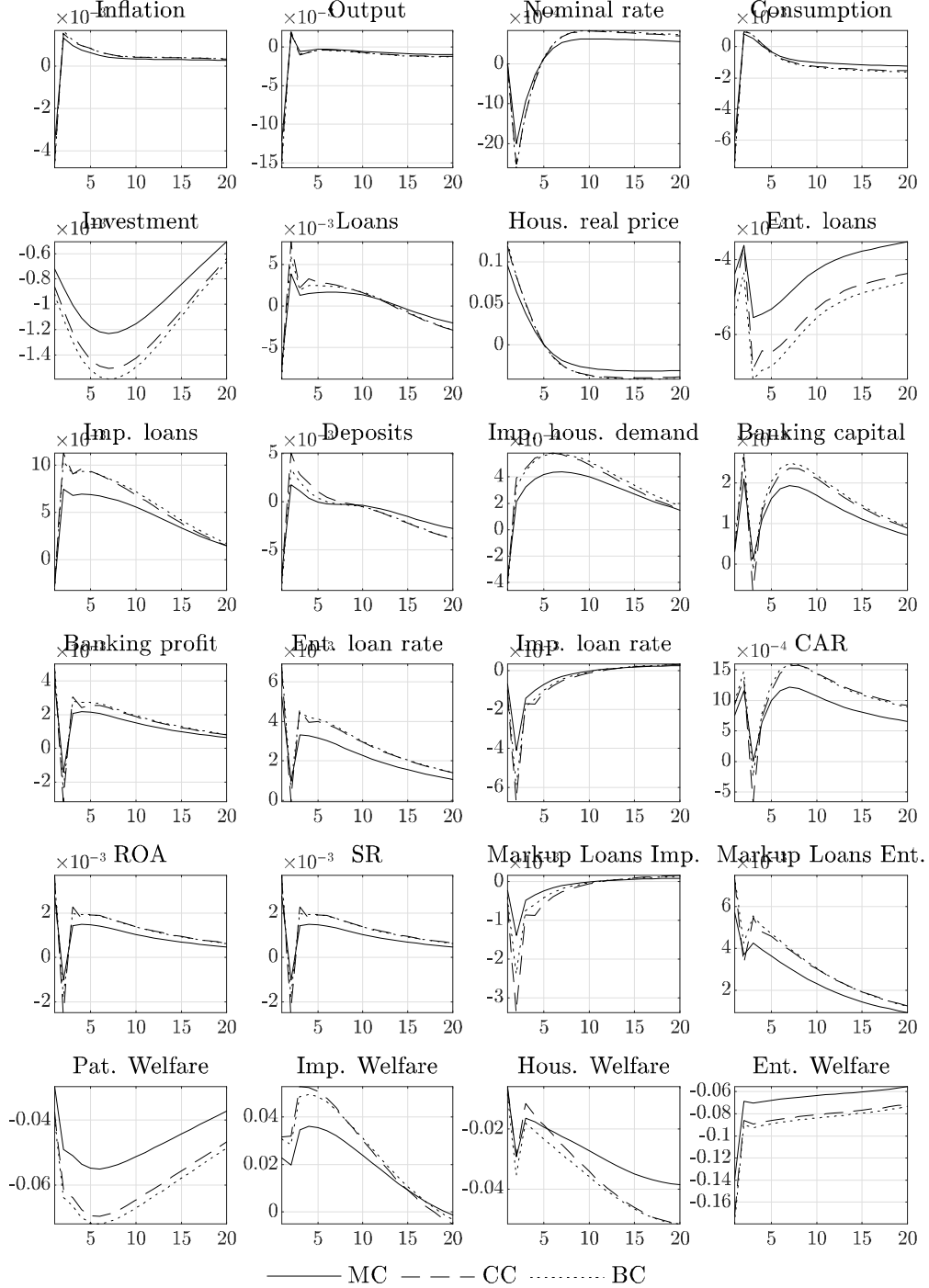
¹⁸Impulse response functions for highly concentrated markets with three banks to less concentrated markets, with five and ten banks, are available upon request. According to the markup equations (Eqs. 33 and 36), bank markups are affected by the number of banks operating in the market. The fewer the banks, the more the markups are affected. Responses of the macroeconomic variables follow the effects on markups. Increases in loans and investments are 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



Notes: This figure depicts the impulse response functions of model variables to a 1% exogenous shock to the loan markup for impatient households. The y-axis measures the percentage point change from the initial state, while the x-axis represents the number of quarters after the shock.

Figure 6: Response to a 1% entrepreneurs' loan markup shock



Notes: This figure depicts the impulse response functions of model variables to a 1% exogenous shock to the loan markup for entrepreneurs. The y-axis measures the percentage point change from the initial state, while the x-axis represents the number of quarters after the shock.

causes BC's markups to tend toward those under PC.¹⁹

5.4 Loan Substitutability and Concentration

Sections 5.1 to 5.3 illustrated the role of the competition market structure in transmitting shocks. In this section, we examine how the level of bank concentration (the number of banks) influences the transmission of financial shocks to the economy, specifically following a shock to the degree of loan substitutability for impatient households and entrepreneurs.

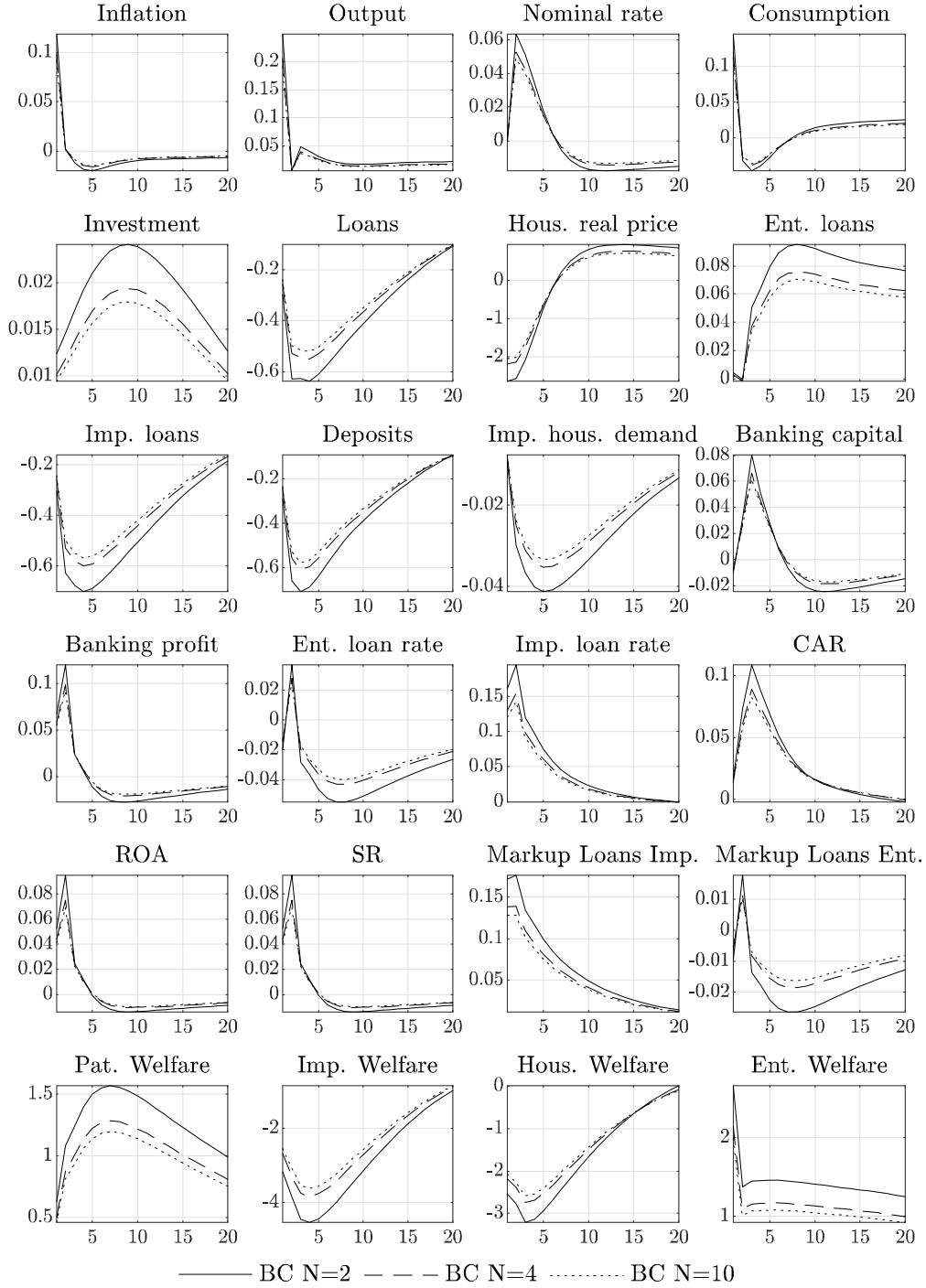
Figs. 7 and 8 present the responses of the economy following an impatient household loan markup shock under CC and BC at different concentration levels. In more concentrated banking markets, banks may set higher rates, leading to increases in their markups. In both competitive market structures (CC and BC), an impatient household loan markup shock under high concentration reduces more impatient loans than in low concentrated banking markets, which in turn reduce more housing demand. This results in greater decreases in unconditional welfare for impatient households in more concentrated markets compared to less concentrated ones.

A comparison of Fig. 7 and 8 shows how competition and concentration influence the transmission of financial shocks. Under BC, increasing concentration leads to a higher decline in loans than under CC. Concentration appears to have a less significant impact on the economy following an impatient household 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 concentration levels. An entrepreneur loan markup shock reduces investment more significantly in high-concentration markets than in low-concentration ones. This decline in investment corresponds to a decrease in aggregate demand, resulting in lower output and (unconditional) welfare for entrepreneurs and households, which is higher under high concentrations than under less concentrated banking markets. The effect of competition market structure on concentration is less significant following an entrepreneurs' loan markup shock than following an impatient households' loan markup shock.

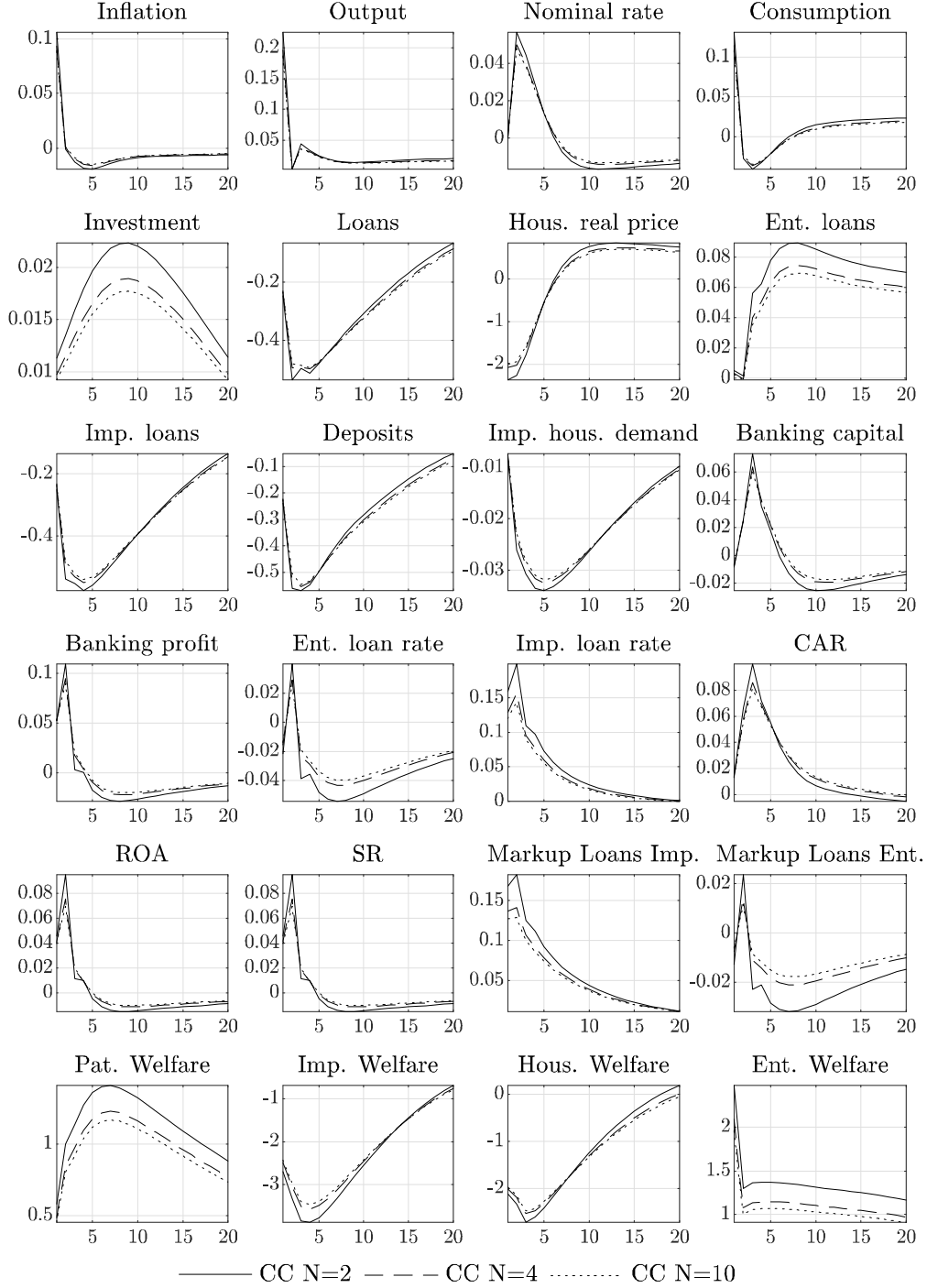
¹⁹Markups are assumed fixed for the monetary policy shock (Fig. 4). Financial shocks influence markups, which influence banks differently. Some strive to preserve markups, while others strive to increase them.

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



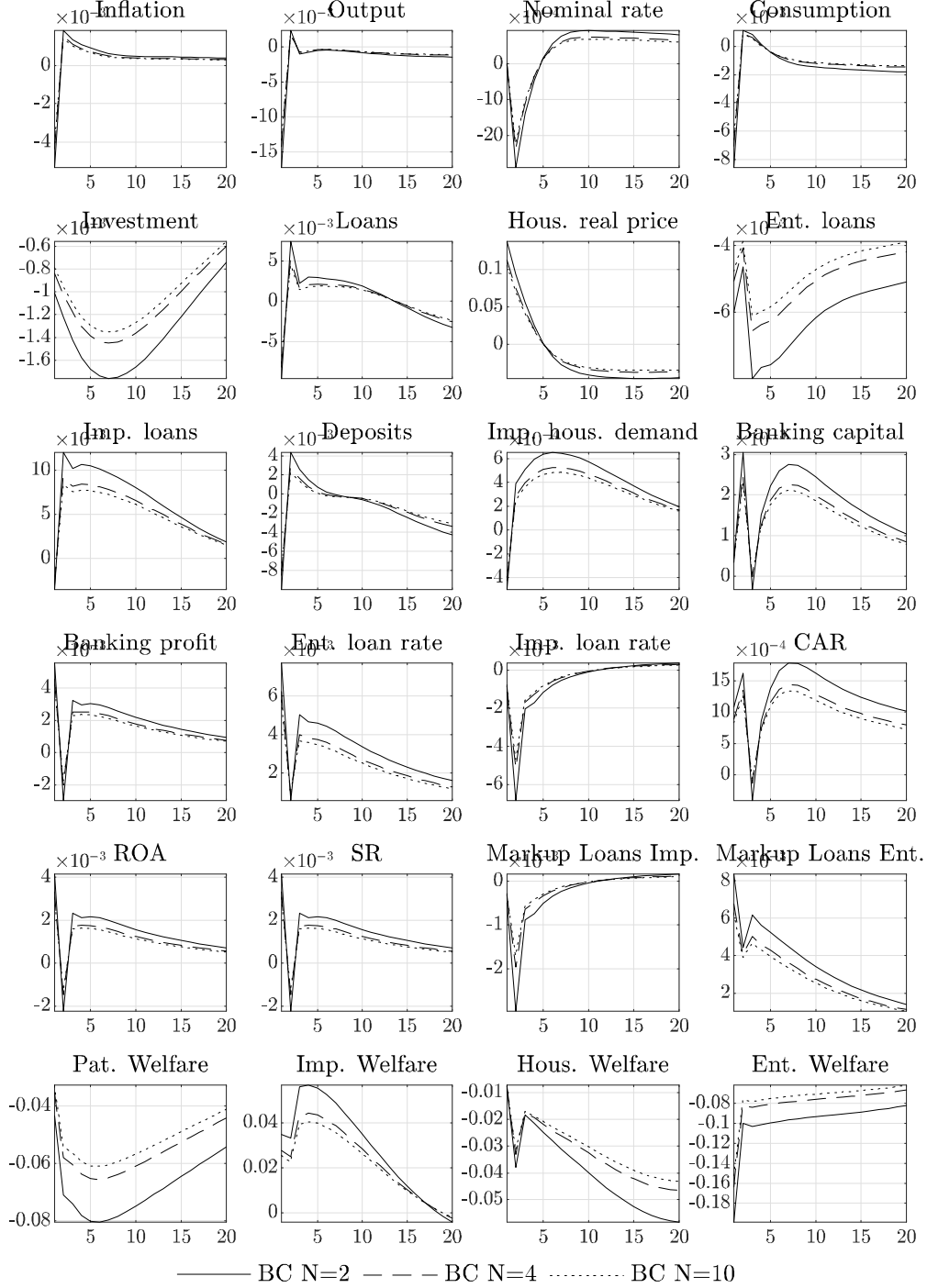
Notes: This figure depicts the impulse response functions of model variables to a 1% exogenous shock to the loan markup for impatient households under BC. The y-axis measures the percentage point change from the initial state, while the x-axis represents the number of quarters after the shock.

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



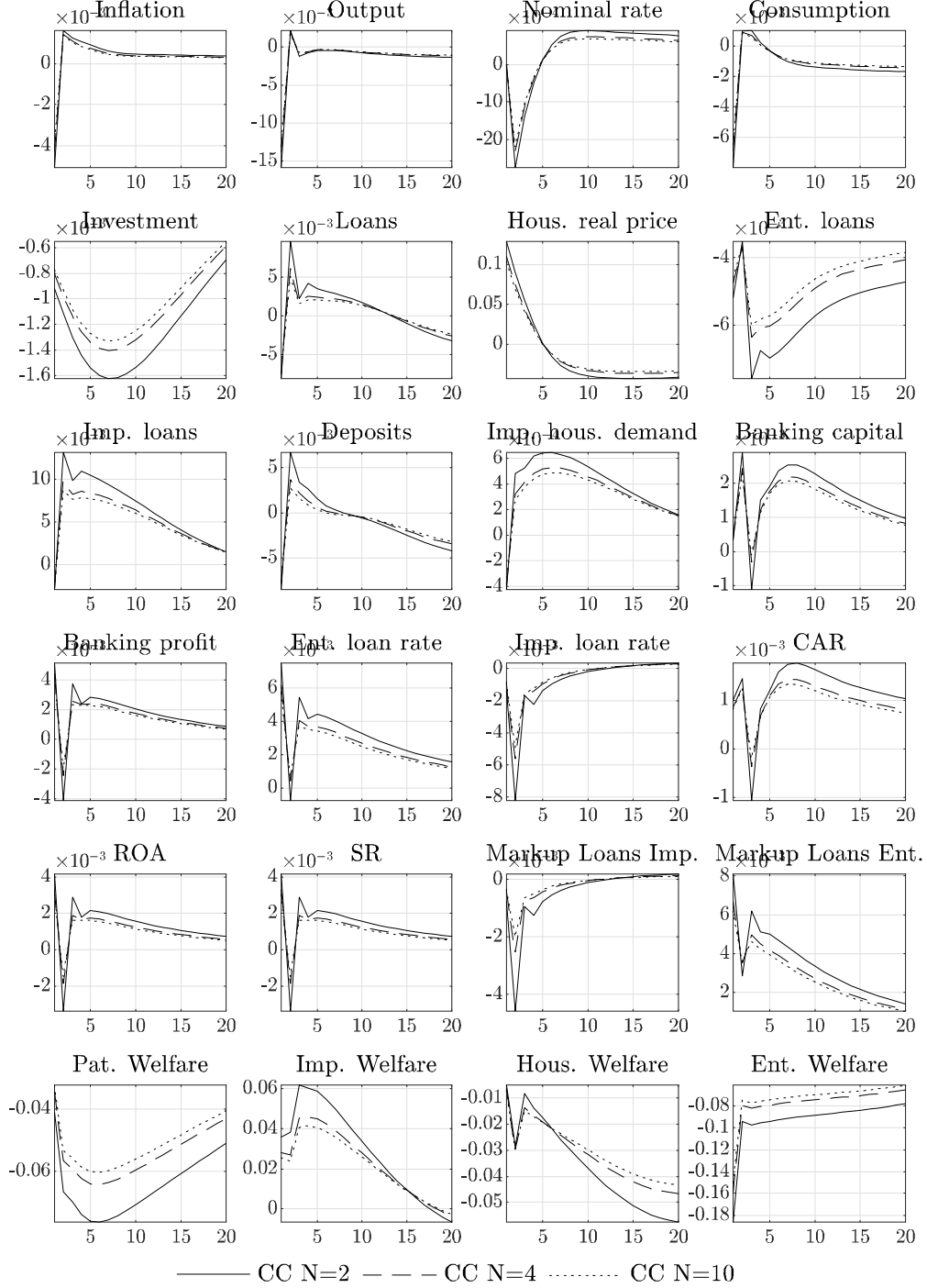
Notes: This figure depicts the impulse response functions of model variables to a 1% exogenous shock to the loan markup for impatient households under CC. The y-axis measures the percentage point change from the initial state, while the x-axis represents the number of quarters after the shock.

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



Notes: This figure depicts the impulse response functions of model variables to a 1% exogenous shock to the loan markup for entrepreneurs under BC. The y-axis measures the percentage point change from the initial state, while the x-axis represents the number of quarters after the shock.

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



Notes: This figure depicts the impulse response functions of model variables to a 1% exogenous shock to the loan markup for entrepreneurs under CC. The y-axis measures the percentage point change from the initial state, while the x-axis represents the number of quarters after the shock.

6 Financial Stability and Welfare

6.1 Financial Stability Transmission Channel

To assess banks' ability to withstand financial shocks without resorting to extreme financial instability scenarios like bank failures, we leverage financial stability ratios that measure the capacity of banks to absorb a financial shock, particularly the CAR, which measures the bank capitalization structure.

In this section, we show the transmission channel of a financial stability shock to social welfare. For this purpose, we analyze the responses of our variables to a positive CAR shock (Fig. 11).

Fig. 11 shows that welfare reacts to changes in banks' equity and, more broadly, to their probability of default. A positive shock to the bank CAR improves agents' welfare. The transmission channel of this shock stems from better-capitalized banks lowering interest rates, which improves credit access for agents. This reduction in margins leads to an increase in the amount of credit granted to households and firms, ultimately enhancing welfare.

Our findings suggest a positive relationship between banking market stability, resulting from better-capitalized banks, and social welfare. This result is driven by our welfare measure, being derived from the utility of households and firms. Since utility considers the ability to borrow and save, when conditions in the banking market improve (deteriorate), banks increase (decrease) their ability to lend, which improves (deteriorates) agents' welfare.²⁰

6.2 Competition Transmission Channel

In this section, we assess the effect of bank competition on welfare and financial stability.

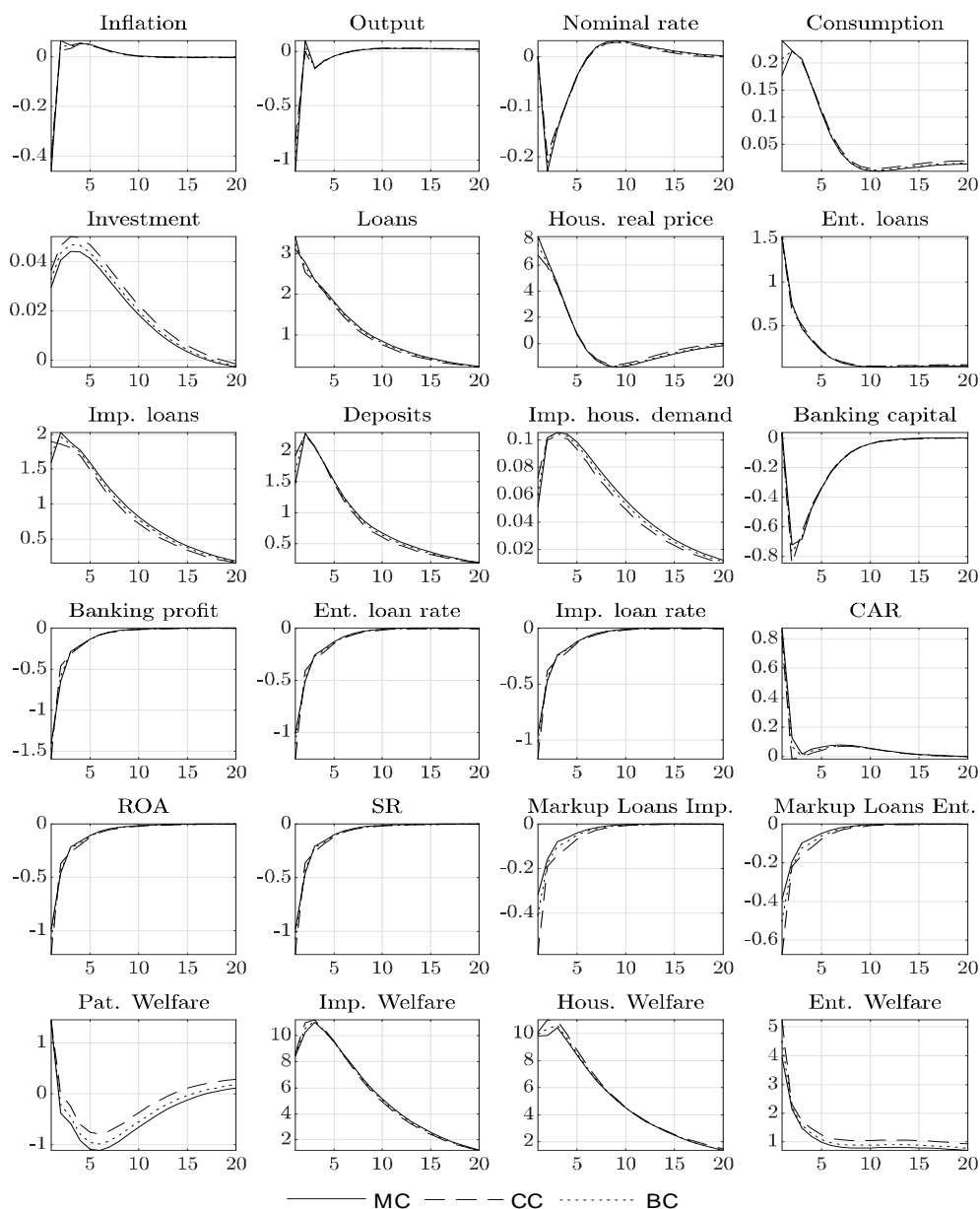
Our model simulation results, which include welfare and financial stability ratios, are obtained by solving the nonlinear model and analytical steady-state at the second-order approximation. In our stochastic context, we compute the simulations corresponding to a random draw of the shocks. The main algorithm for solving stochastic models relies on a Taylor approximation to the second order of the expectation functions (Judd, 1996; Collard and Juillard, 2001a,b; Schmitt-Grohé and Uribe, 2004). We compute the Taylor approximation of the model around the deterministic steady state and solve the decision and transition functions for the approximated model. Impulse response functions and descriptive statistics are computed,²¹ including the average of each variable (e.g., welfare and financial stability ratios) for each concentration and competition type. These averages are used in the below figures to analyze the trade-off between social welfare and financial stability ratios.

Fig. 12 presents simulated household's welfare (CEV), CAR, SR, and ZS financial stability ratios.

²⁰Our model does not simulate extreme cases such as bank failures, but highlighting this relationship implies that financial stability impacts agents' welfare.

²¹Moments, variance decomposition, correlation and autocorrelation coefficients, etc.

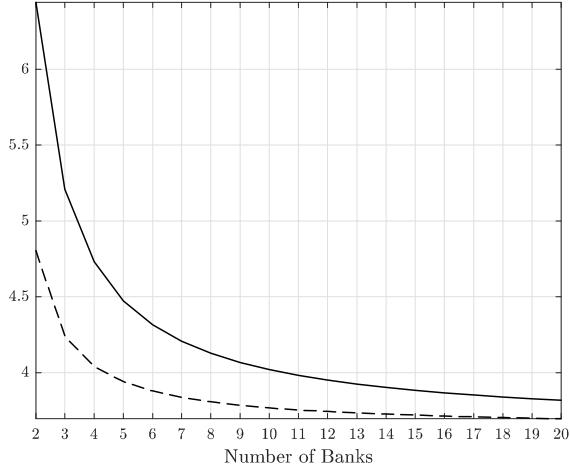
Figure 11: Response to a 1% CAR shock



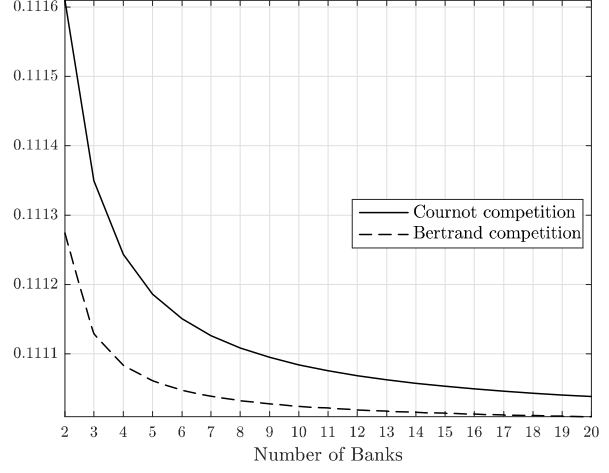
Notes: This figure depicts the impulse response functions of model variables to a 1% shock to the CAR in a banking system with four banks. The y-axis measures the percentage point change from the initial state, while the x-axis represents the number of quarters after the shock.

Figure 12: Welfare and Financial Stability.

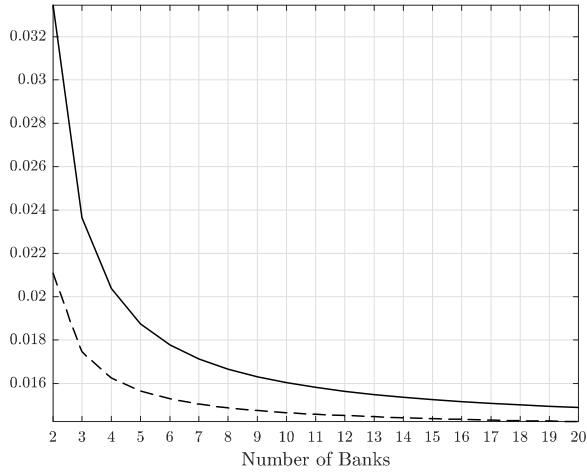
Panel 1: Household's Welfare CEV



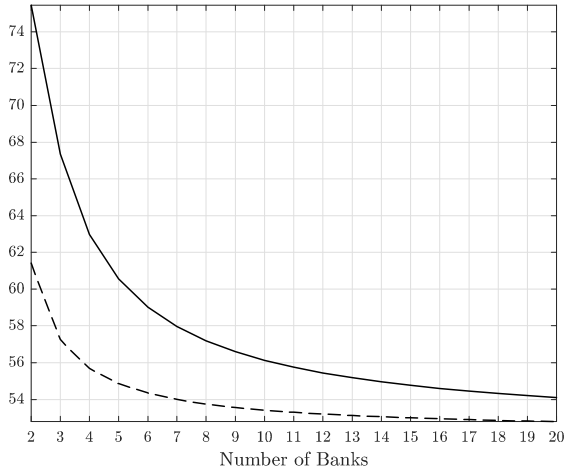
Panel 2: Capital Adequacy Ratio (CAR)



Panel 3: Solvency Ratio (SR)



Panel 4: Z-Score (ZS)



Notes: The solid and dashed lines stand for CC and BC, respectively. These welfare and financial stability results are not normalized and only consider household welfare. Lower welfare CEV values correspond to more desirable states (Garín et al., 2016), as Panel 1 presents welfare losses (see Section 2.7).

In our simulation, PC is considered the benchmark because banks have no market power under PC, resulting in zero markups (i.e., making it the preferred model by agents in terms of social welfare). We rely on PC only as a reference point for our welfare analysis since PC assumptions are difficult to observe in practice. Therefore, we define social welfare in compensating variation, equivalent to the consumption equivalent welfare (CEV), as measuring how much consumption households have to give up in each period to remain in CC or BC.

Our results demonstrate that the oligopolistic market structure worsens agents' welfare compared to the PC market structure (Panel 1, Fig. 12). Furthermore, we find that BC is always preferred to CC (Vives, 1984), regardless of the number of banks in the market. Households have to give up 6.5% of their consumption to remain in CC, compared to 4.7% to remain in BC when there are two banks in the market.

The number of banks also plays a key role in household welfare. We find that concentration negatively affects welfare (Panel 1, Fig. 12), in that decreased banking concentration reduces household welfare loss. These results highlight the connection between market concentration and bank markups. When the banking market consolidates (fewer banks), banks have greater ability to set higher markups. This, in turn, leads to a decline in consumer surplus and social welfare. Within each imperfect competition market structure, welfare improves as the number of banks increases. Ultimately, the highest welfare levels are theoretically achievable with an infinite number of banks.

Fig. 12 (Panels 2 to 4) presents the simulations of the financial stability ratios defined in Section 2.6 (CAR, SR, and ZS). The simulations highlight that a lower concentration in the banking market decreases financial stability for each ratio.²² These results support the *competition-fragility* view, which claims that increased market competition erodes market power, leading to lower markups and a reduced franchise value. This, in turn, encourages banks to engage in riskier behavior, thus reducing the stability of the banking sector.

6.3 Welfare-Financial Stability Trade-Off

The originality of our results lies in the comparison of the effect of competition and concentration on unconditional welfare CEV and financial stability ratios. This comparison is interesting because it expands upon the results of the *competition-fragility* view that only considers the effects on financial stability.²³

For each economy with N banks, the mean welfare CEV for each agent $\kappa = \{p, i, e\}$ and competition type $c = \{CC, BC\}$ is denoted as $\overline{CEV}_{\kappa, c, N}$, and the

²²The decrease of the CAR ratio is limited to 0.11, which is the minimum level of bank capitalization imposed by the regulation.

²³We focus on these two variables because the information they provide is relevant. Indeed, the literature extensively discusses the relationship between bank competition and financial stability (Keeley, 1990; Mishkin, 1999; Allen and Gale, 2004b; Boyd and De Nicoló, 2005; Beck et al., 2006, 2013), and makes macroprudential recommendations regarding bank competition. However, these recommendations ignore the potential welfare effects of bank concentration. Comparing the effect of banking competition on financial stability with its effect on welfare allows us to improve the macroprudential recommendations given by the literature.

financial stability mean-ratio is denoted as $\overline{FS}_{\mathcal{X},c,N}$, where $FS = \{CAR, ZS, SR\}$.

As $\overline{CEV}_{\mathcal{X},c,N}$ represents the compensating variation as a welfare loss from PC, more desirable competition and concentration states coincide with lower values of the compensating variation. The normalized mean-welfare compensating variation considers growth variations from initial points for each number of banks, such that $\Gamma_{\mathcal{X},c,N} = \Gamma_{\mathcal{X},c,N-1} \frac{\overline{CEV}_{\mathcal{X},c,N}}{\max_N(\overline{CEV}_{\mathcal{X},c,N})}$, where $\forall \mathcal{X}, c, \Gamma_{\mathcal{X},c,1} = 1$.

The financial stability mean-ratios are decreasing functions of N , thus the normalized mean-financial stability ratio also considers growth variations from initial points for each number of banks, such that $\Phi_{\mathcal{X},c,N} = \Phi_{\mathcal{X},c,N-1} \frac{\overline{FS}_{\mathcal{X},c,N}}{\max_N(\overline{FS}_{\mathcal{X},c,N})}$, where $\Phi_{\mathcal{X},c,1} = 1$.

The desirable number of banks maximizes the weighted average of normalized welfare and financial stability measures, $(1 - \Gamma)^\omega + \Phi^{1-\omega}$, where ω represents the policymaker's preference towards welfare relative to financial stability, and $1 - \Gamma$ represents the welfare gain.²⁴ This approach represents the policy frontier, illustrating the trade-off of the central bank (regulator), and allows us to assess the number of banks that is desirable to maximize welfare and financial stability.²⁵

Fig. 13 compares the effect of competition and concentration on household (patient and impatient) welfare and financial stability.

The maximum point on the welfare-financial stability trade-off curve represents the desirable number of banks. Fig. 13 assumes a policymaker valuing social welfare and financial stability objectives equally ($\omega = 0.50$).

Table 5 summarizes the results for all types of agents.

Table 5: Desirable Banking Concentration

	CAR		SR		ZS		Average	
	BC	CC	BC	CC	BC	CC	BC	CC
Households ($CEV_{h,t}$)	13	8	5	4	8	5	9	6
Entrepreneurs ($CEV_{e,t}$)	9	6	5	4	7	5	7	5
Total (CEV_t)	12	7	5	4	7	5	8	5

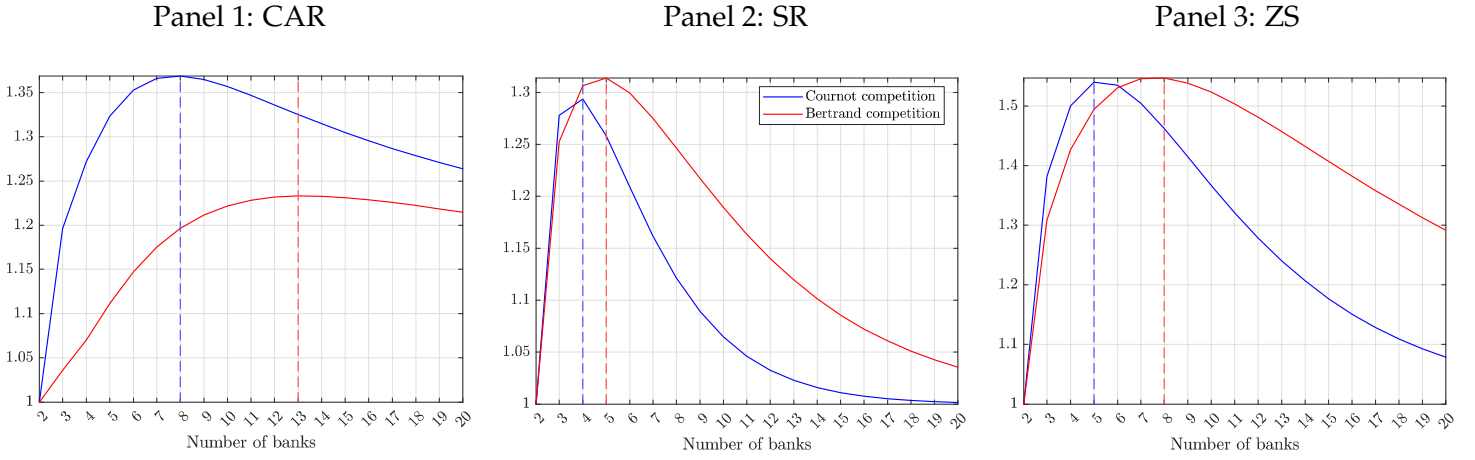
Notes: The numbers define the desirable number of banks in the economy, assuming the number of households is the same as that of entrepreneurs, where patient and impatient households are equally distributed, and the policymaker equally weighs welfare and financial stability. Results for different weighting or distribution assumptions are available upon request.

According to these financial stability indicators, our findings suggest that the

²⁴As the number of banks increases, the normalized welfare loss starts at one and tends towards zero (Γ is a decreasing function of the number of banks), while the welfare gain starts to zero and tends to one ($1 - \Gamma$ is an increasing function of the number of banks). This implies a negative effect of bank concentration on welfare CEV gains. This harmonization from losses to gains is necessary in order to compare welfare gains with financial stability gains.

²⁵Computing this weighted average without normalizing its components may lead to different results due to the different natures of welfare (compensating variation) and financial stability (ratio) indicators.

Figure 13: Welfare and Financial Stability.



Notes: The blue and red lines represent the welfare-financial stability trade-off curves for households under CC and BC, respectively. The dashed lines represent the desirable number of banks, i.e., the maximum of the welfare-financial stability trade-off curves.

desired number of banks is between five and eight on average. For instance, the maximum of the curve for the CAR ratio is reached at eight banks under CC, and thirteen under BC, as far as household compensating variation welfare is concerned (Table 5). For SR, the desirable number of banks is four under CC and five under BC. Finally, the desirable number of banks is five under CC and eight under BC, as far as ZS is concerned.

Overall, our model suggests that a banking market under CC should have five banks, and that a market under BC should have eight, on average. Results favoring a concentrated market for the US are robust, regardless of the measure of financial stability.

Table 6 lists the desirable number of banks, assuming that the policymaker prefers financial stability over social welfare (70%-30%).

Table 6: Desirable Banking Concentration - Policymaker Preferences

	CAR		SR		ZS		Average	
	BC	CC	BC	CC	BC	CC	BC	CC
Households ($CEV_{h,t}$)	10	5	3	3	5	4	6	4
Entrepreneurs ($CEV_{e,t}$)	6	4	4	3	5	4	5	4
Total (CEV_t)	9	4	3	3	5	4	6	4

Notes: The numbers define the desirable number of banks in the economy, assuming the number of households is identical to that of entrepreneurs and patient and impatient households are equally distributed. These results assume the policymaker prefers financial stability over welfare, assigning 70% and 30% weights, respectively. Different weighting and distribution scenarios are available upon request.

As expected from Fig. 13, a policymaker more concerned about maximizing

financial stability over social welfare should decrease the number of banks in the economy. In most cases, comparing Tables 5 and 6 yielded significant differences, some due to policymakers' preferences generating compensation effects.

Our results theoretically show that decreasing market power leads to greater welfare gains than a reduction in bank profitability, highlighting the importance of policy measures to eliminate entry barriers.²⁶ These findings align with Fernández de Guevara and Maudos (2007), who empirically showed that the welfare gains of reducing market power in the banking sector outweigh the financial stability costs of doing so.

Fig. 13 explains the welfare-financial stability trade-off, while clarification is needed regarding the desirability of extreme cases from the standpoint of financial stability and social welfare. Indeed, the most desirable value of one is associated with the less desirable value of the other. Therefore, our approach reflects the notion that only the intermediate situation is desirable, and neither the minimum nor the maximum value of welfare or financial stability is. By doing so, we can identify policy interventions that can improve the objectives and desirability of both of these policy variables.

7 Interpretation and Policy Implications

Our model assumes that banks' interest rate setting behavior depends on the concentration of the banking sector. Indeed, considering the number of banks as a determinant of profit margins amplifies the response mechanism of variables to shocks. Therefore, a model that does not consider banking sector concentration could underestimate the effects of real and financial shocks. This result is particularly due to the effect of bank size in our model: when the banking market is more concentrated, the size of banks increases, and shocks are amplified. Although our result does not account for a change in banks' risk-taking behavior due to market concentration, the effect of bank size indicates that a banking market with a few large banks is more fragile than one with many small banks, suggesting that banks' behavior may be riskier due to moral hazard, thus reinforcing bank fragilities and further amplifying shocks.

Our second analysis evaluates concentration effects on welfare and financial stability, showing that a concentrated banking sector worsens the welfare of households and firms compared to a less concentrated one. In contrast, higher concentration in the banking system improves financial stability, suggesting consolidation should reduce banks' risk-taking behavior (static analysis). The description of the underlying mechanism is as follows: 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 and so their liquidity, which deteriorates consumer surplus and, finally, social welfare.²⁷

Reconciling these two effects allows us to establish a desirable banking sector

²⁶Slopes of welfare and financial stability dynamics are available upon request.

²⁷Our model ignores the probability of bank default. However, we expect it to be positively correlated with the financial stability ratios, particularly the ZS (Hafeez et al., 2022).

concentration, reducing welfare losses and augmenting financial stability indicators. This desired concentration ranges from four to six banks, on average, depending on the market structure and the central banker's preferences.²⁸

These results relate to the debate on banking competition. Indeed, while some favor banking sector competition, arguing for greater credit availability, policy-makers must consider its potential negative implications on financial stability.

However, this analysis has limitations. The financial shocks discussed are credit crunch scenarios, and the model does not consider the risk of bank default or extreme shocks.²⁹ Furthermore, the situation of banks before the shocks (initial state) is unknown. Banking concentration could be linked to a better initial situation in the banking sector, reducing the probability of financial crises (Jeasakul et al., 2014). Moreover, our macroeconomic model and results do not include small banks or financial institutions, 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. However, the heterogeneous banking sector should push financial stability ratios to the left to emphasize the riskier banking market structure compared to our homogeneous sector. Our theoretical findings are likely to remain unchanged when considering these two dynamics. Moreover, as our model is calibrated with US data, the results will likely change for countries other than the US with different sizes and economic, financial system, and regulatory structures. More empirical analyses specific to each country are necessary to determine the corresponding desirable number of banks. Comparative research would rely on different calibrations and estimations, leading to differences in the desirable number of banks across countries. Finally, although we consider monetary policy shocks, optimal monetary policy, monetary policy frameworks and rules are outside the scope of this article. Our theoretical model does not also consider shadow banks, small banks with limited services, and the frequency at

²⁸Some policymakers may prefer financial stability at the cost of social welfare, while others may prefer to preserve social welfare at the cost of financial stability.

²⁹Popular DSGE models do not consider extreme shocks or the failure of households and firms (Smets and Wouters, 2007; Galí, 2008; Gerali et al., 2010). Some assume no market frictions or rational expectations, which assumes that all households and firms operate in a perfectly competitive market and have perfect information. Although these assumptions do not hold in real-world situations, especially in times of crisis or severe economic shocks, these models help address research questions in normal times and are useful for policy analysis. Extreme shocks, such as natural disasters, pandemics, or financial crises, can have significant and lasting economic effects (e.g., bank and household failure). Most linear DSGE models cannot capture these situations, assuming the economy always returns to a steady state in the long run, failing to account for household and firm failure. Bankruptcies and defaults can lead to a chain reaction, leading to a credit crunch and a significant contraction in economic activity. These effects can be exacerbated by high levels of debt or leverage, leading to a rapid and systemic collapse of the financial system and complete financial instability. To address these limitations, researchers have developed alternative models that consider the possibility of extreme shocks and household and firm failure, leading to complex and non-linear dynamics. While DSGE models are helpful for macroeconomic analysis, some limitations may not need to be addressed to focus on normal economic situations. Accounting for extreme shocks and household and firm failure can lead to a more accurate understanding of the dynamics of the economy and inform better policy interventions to mitigate the impact of crises and promote stability at the cost of high complexity.

which policymakers change the number of banks. An example of the latter 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 from a trade-off between reduced welfare and increased financial stability.

Our study provided two sets of results. The first set of results shows 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 imperfect competition, an infinite number of banks are preferred over a limited number of banks. Finally, competition in price (BC) is always preferred to competition in quantities (CC) regardless of the number of banks.

We analyze the effect of competition on financial stability, using three measures. Our results favor the *competition-fragility* view, arguing that a less competitive market increases bank markups and reduce risk-taking, which fosters financial stability. Specifically, we find that financial stability measures are lower when the market is less concentrated. 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 four and six.

These findings have direct implications for policymakers. First, they validate the importance of considering financial stability and welfare 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.

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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:

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

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. ν 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 $\epsilon_{z,t}$ 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

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

where $q_{h,t} = Q_{h,t}/P_t$ is the real housing price and $Q_{h,t}$ is nominal housing price. π_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

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

$$\frac{\nu}{h_{p,t}} = \frac{q_{h,t} \epsilon_{z,t}}{c_{p,t}} - \beta_p \mathbb{E}_t \left[q_{h,t+1} \epsilon_{z,t+1} \frac{1}{c_{p,t+1}} \right], \quad (49)$$

$$l_{p,t}^\varphi = w_{p,t} \epsilon_{z,t} \frac{1}{c_{p,t}}. \quad (50)$$

A.2 Impatient Households

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

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

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). $\epsilon_{z,t}$ is the same preference shock experienced by both the households.

Impatient household decisions are made according to the following budget constraint

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

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

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

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.³⁰ Impatient households are constrained to borrow $b_{i,t}$ to a certain limit.³¹

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

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

$$\frac{\nu}{h_{i,t}} = q_{h,t} \epsilon_{z,t} \frac{1}{c_{i,t}} - \beta_i \mathbb{E}_t \left[q_{h,t+1} \epsilon_{z,t+1} \frac{1}{c_{i,t+1}} + \lambda_{i,t} m_{i,t} q_{h,t+1} \pi_{t+1} \right], \quad (55)$$

$$l_{i,t}^\varphi = w_{i,t} \epsilon_{z,t} \frac{1}{c_{i,t}}. \quad (56)$$

A.3 Entrepreneurs

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

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

³⁰Equal to $(1 - m_{i,t}) \mathbb{E}_t [q_{h,t+1} h_{i,t} \pi_{t+1}]$

³¹Equal to $m_{i,t} \mathbb{E}_t [q_{h,t+1} h_{i,t} \pi_{t+1} / (1 + R_t^{b_i})]$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

such that each retailer faces an individual demand curve:

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

Retailers choose $P_t(z)$ to maximize

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

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.

$$1 - \epsilon_t + \frac{\epsilon_t}{X_t} - \kappa_p \left(\pi_t - \pi_{t-1}^{l_p} \pi^{1-l_p} \right) \pi_t + \beta_p \left(\frac{\epsilon_{z,t+1}}{\epsilon_{z,t}} \frac{c_{i,t}}{c_{i,t+1}} \right) \kappa_p \left(\pi_{t+1} - \pi_t^{l_p} \pi^{1-l_p} \right) \pi_{t+1} \frac{y_{t+1}}{y_t} = 0. \quad (69)$$

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.³²

³²We assume that old capital can be converted into new capital and that the transformation of the final good is subject to quadratic adjustment costs.

The amount of capital goods produced is

$$k_{e,t} = (1 - \delta_{ke})k_{e,t-1} + \left[1 - \frac{\kappa_i}{2} \left(\frac{\epsilon_{qk,t} \dot{i}_t}{\dot{i}_{t-1}} - 1 \right)^2 \right] \dot{i}_t, \quad (70)$$

where κ_i is the adjustment cost of a change in investment and $\epsilon_{qk,t}$ 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 condition is

$$\begin{aligned} 1 = & q_{k,t} \left(1 - \frac{\kappa_i}{2} \left(\frac{\epsilon_{qk,t} \dot{i}_t}{\dot{i}_{t-1}} - 1 \right)^2 - \kappa_i \left(\frac{\epsilon_{qk,t} \dot{i}_t}{\dot{i}_{t-1}} - 1 \right) \left(\frac{\epsilon_{qk,t} \dot{i}_t}{\dot{i}_{t-1}} \right) \right) \\ & + \beta_e \left(\frac{c_{e,t}}{c_{e,t+1}} \right) q_{k,t+1} \kappa_i \left(\frac{\epsilon_{qk,t+1} \dot{i}_{t+1}}{\dot{i}_t} - 1 \right) \left(\frac{\epsilon_{qk,t+1} \dot{i}_{t+1}}{\dot{i}_t} \right)^2. \end{aligned} \quad (71)$$

A.6 Monetary Policy

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

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

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, $\epsilon_{r,t}$ exogenous fluctuations in the nominal interest rate, and $\bar{\pi}$ denotes steady-state inflation rate.

A.7 Market Clearing

Market clearing in the goods market is

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

and the market clearing 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

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

where $X_t \in \{A_{e,t}, m_{i,t}, m_{e,t}, \epsilon_t, \epsilon_{qk,t}, \epsilon_{z,t}, \epsilon_{r,t}\}$, \bar{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

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

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

$$\frac{v}{h_{p,t}} = \frac{q_{h,t} \epsilon_{z,t}}{c_{p,t}} - \beta_p \mathbb{E}_t \left[q_{h,t+1} \epsilon_{z,t+1} \frac{1}{c_{p,t+1}} \right], \quad (80)$$

$$l_{p,t}^\varphi = w_{p,t} \epsilon_{z,t} \frac{1}{c_{p,t}}. \quad (81)$$

B.2 Impatient households

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

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

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

$$\frac{v}{h_{i,t}} = q_{h,t} \epsilon_{z,t} \frac{1}{c_{i,t}} - \beta_i \mathbb{E}_t \left[q_{h,t+1} \epsilon_{z,t+1} \frac{1}{c_{i,t+1}} + \lambda_{i,t} m_{i,t} q_{h,t+1} \pi_{t+1} \right], \quad (85)$$

$$l_{i,t}^\varphi = w_{i,t} \epsilon_{z,t} \frac{1}{c_{i,t}}. \quad (86)$$

B.3 Entrepreneurs

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

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

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

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

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

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

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

B.4 Retailers

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

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

B.5 Capital producers

$$k_{e,t} = (1 - \delta_{ke}) k_{e,t-1} + \left[1 - \frac{\kappa_i}{2} \left(\frac{\epsilon_{qk,t} \dot{i}_t}{\dot{i}_{t-1}} - 1 \right)^2 \right] \dot{i}_t, \quad (96)$$

$$\begin{aligned} 1 &= q_{k,t} \left(1 - \frac{\kappa_i}{2} \left(\frac{\epsilon_{qk,t} \dot{i}_t}{\dot{i}_{t-1}} - 1 \right)^2 - \kappa_i \left(\frac{\epsilon_{qk,t} \dot{i}_t}{\dot{i}_{t-1}} - 1 \right) \left(\frac{\epsilon_{qk,t} \dot{i}_t}{\dot{i}_{t-1}} \right) \right) \\ &+ \beta_e \left(\frac{c_{e,t}}{c_{e,t+1}} \right) q_{k,t+1} \kappa_i \left(\frac{\epsilon_{qk,t+1} \dot{i}_{t+1}}{\dot{i}_t} - 1 \right) \left(\frac{\epsilon_{qk,t+1} \dot{i}_{t+1}}{\dot{i}_t} \right)^2. \end{aligned} \quad (97)$$

B.6 Monetary policy

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

B.7 Wholesale bank

$$K_{b,t} + D_t = B_t, \quad (99)$$

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

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

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

B.8 Deposit branch

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

B.9 Loan branch: Monopolistic competition

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

B.10 Loan branch: Cournot competition

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

B.11 Loan branch: Bertrand competition

$$R_t^{b_k} = R_{b,t} \frac{(\varsigma_{b_k,t} (1 - N) - 1)}{(1 - \varsigma_{b_k,t}) (N - 1)}. \quad (106)$$

B.12 Market clearing conditions

$$y_t = c_{p,t} + c_{i,t} + c_{e,t} + i_t, \quad (107)$$

$$h_{p,t} + h_{i,t} = 1, \quad (108)$$

$$l_t = l_{p,t} + l_{i,t}, \quad (109)$$

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

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).

$$y = 1, \quad (111)$$

$$\pi = 1, \quad (112)$$

$$q_k = 1, \quad (113)$$

$$R^d = \frac{\pi}{\beta} - 1, \quad (114)$$

$$x = \frac{\epsilon}{\epsilon - 1}, \quad (115)$$

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

$$R = \frac{\varsigma_{d,t} - 1}{\varsigma_{d,t}} R^d, \quad (117)$$

$$R_b = R \quad (118)$$

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

$$B = b_e + b_i, \quad (120)$$

$$K_b = Bv, \quad (121)$$

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

$$i = \delta_k k_e, \quad (123)$$

$$d = b_e + b_i - K_b, \quad (124)$$

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

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

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

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

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

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

$$h_p = \frac{vc_p}{(1 - \beta_p)} \left(\frac{1}{q_h} \right), \quad (131)$$

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

$$q_h = \frac{vc_p}{(1 - \beta_p)} + \frac{b_i (1 + R^{b_i})}{m_i \pi}, \quad (133)$$

$$w_p = \alpha (1 - \mu) \frac{y}{xl_p}, \quad (134)$$

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

$$w_i = (1 - \alpha) (1 - \mu) \frac{y}{xl_i}, \quad (136)$$

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

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

$$l = l_p + l_i, \quad (139)$$

$$w = w_p + w_i. \quad (140)$$

Under MC,

$$R^{b_i} = \frac{\varsigma_{b_i}}{\varsigma_{b_i} - 1} R_b, \quad (141)$$

$$R^{b_e} = \frac{\varsigma_{b_e}}{\varsigma_{b_e} - 1} R_b. \quad (142)$$

Under CC,

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

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

Under BC,

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

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

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) \times (NCBDBIQ027S)/LTF + (MPRIME) \times ((BLNECLBSNNCB) + (OLALBSNNCB) + (NNBDILNECL) + (OLALBSNNB))/LTF + (MORTGAGE30US) \times ((MLBSNNCB) + (NNBTML))/LTF.

Nominal interest rate on loans to households (NIROLTHH) = (MORTGAGE30US) \times (HNOTMLQ027S)/LTHH + (TERMCBAUTO48NS) \times (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

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

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

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

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

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

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

$$RATE_t = \frac{FEDFUNDS_t}{4} \quad (153)$$

$$HHRATE_t = \frac{NIROLTF_t}{4} \quad (154)$$

$$ENTRATE_t = \frac{NIROLTHH_t}{4} \quad (155)$$

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

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

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

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).

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

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

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

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

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

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

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

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

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

$$ENT_LOAN_{obs,t} = \ln \left(\frac{b_{e,t}}{b_e} \right) \quad (168)$$

$$HH_LOAN_{obs,t} = \ln \left(\frac{b_{i,t}}{b_i} \right) \quad (169)$$

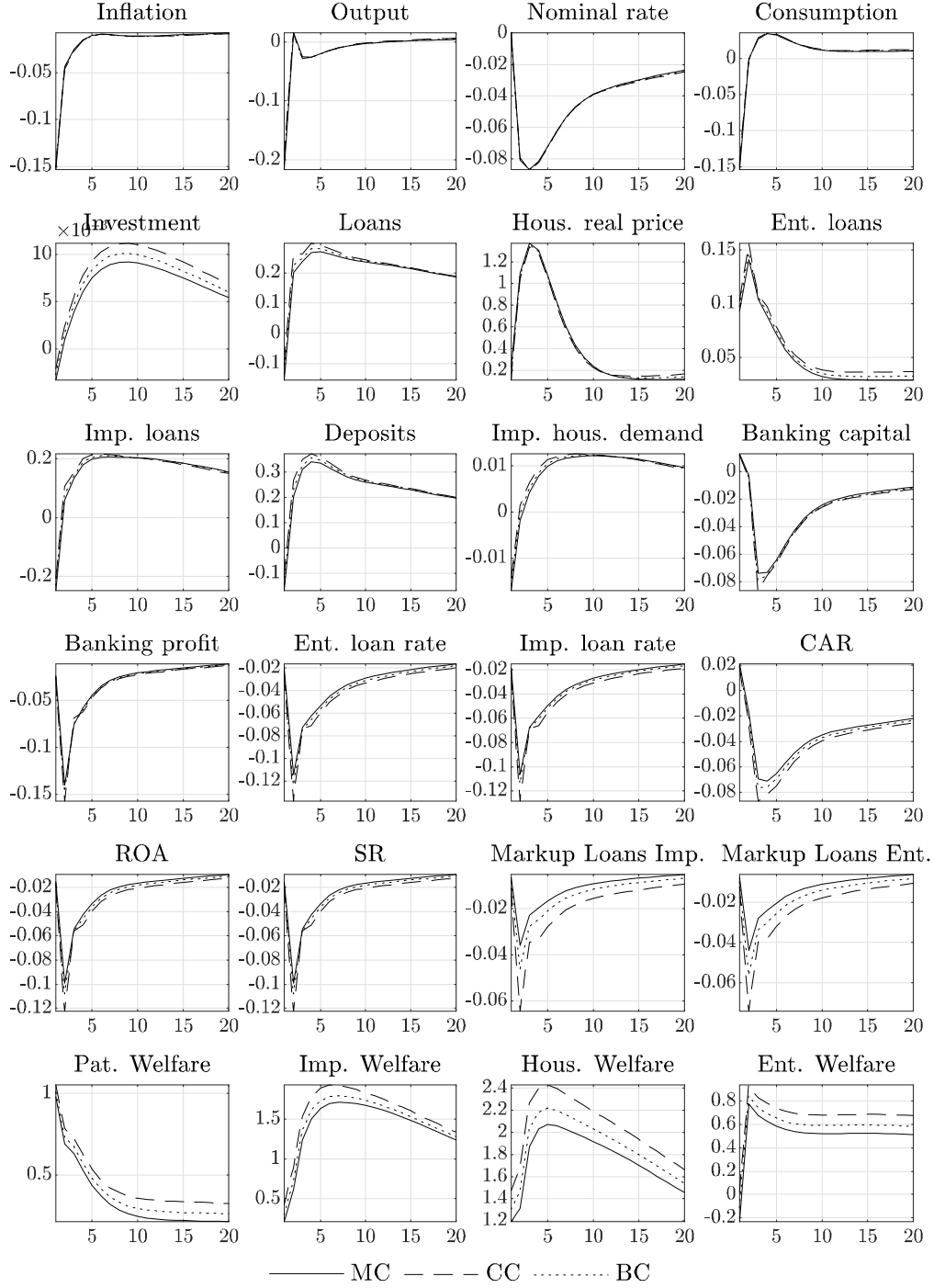
$$DEPOSIT_{obs,t} = \ln \left(\frac{d_t}{d} \right) \quad (170)$$

G Deposit Markup Shock

Fig. 14 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 14: Response to a 1% deposit markup shock



Notes: This figure depicts the impulse response functions of model variables to a 1% exogenous shock to the deposit markup. The y-axis measures the percentage point change from the initial state, while the x-axis represents the number of quarters after the shock.