Large Banks, Loan Rate Markup, and Monetary Policy*

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A large body of empirical evidence suggests that bank loan margins are countercyclical. We develop a model where a countercyclical spread arises due to the strategic interaction between large intermediaries—i.e., banks whose individual behavior affects macroeconomic outcomes–and the central bank. We uncover a new mechanism related to market power of banks which amplifies the impact of monetary and technology shocks on the real economy. The level of the spread is positively connected to the level of entrepreneurs' leverage, and the amplification effect is stronger the more aggressive the central bank's response to inflation.

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1. Introduction

A large body of empirical evidence suggests that bank loan markups tend to move countercyclically along the business cycle (Angelini

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and Cetorelli 2003; Corbae and D'Erasmo 2013; Dueker and Thornton 1997; Mandelman 2011). This relation has been typically attributed to the cyclical properties of borrowers' riskiness, which tends to increase the cost of external finance during recessions (e.g., Bernanke, Gertler, and Gilchrist 1999). Some papers, however, have provided evidence in support of a countercyclical behavior of price-cost margins *independent* of borrowers' riskiness (Olivero 2010). On theoretical grounds, this relation has usually been explained by the existence of sunk or switching costs, sluggish interest rate setting, horizontal product differentiation, the existence of a small number of dominant banks, and a fringe of smaller competitors (Aliaga-Díaz and Olivero 2010b; Andrés and Arce 2012; Corbae and D'Erasmo 2013; Gerali et al. 2010; Mandelman 2011; Olivero 2010).

In this paper we build a model in which countercyclical markups arise due to the presence of a finite number of *large* banks. This new mechanism relies on the strategic interaction between the banks—which internalize the negative aggregate demand effects of their actions in their loan-pricing decisions—and the central bank—which sets the policy rate corresponding to the banks' funding cost. In this setup, market power—and therefore the bank loan margins—depends on the elasticity of the *aggregate loan demand* and of the *policy rate* to changes in the loan rate.[1] These elasticities, in turn, crucially depend on the degree of borrowers' leverage, which affects the responsiveness of aggregate investment and output to a rise in the lending rate. Since leverage is countercyclical in the model, this channel generates a negative relation between GDP and the loan spread.

The strategic interaction between the banks and the monetary authority amplifies the impact of exogenous shocks on the economy, bringing forth a new type of *financial accelerator*, which is crucially related to the presence of non-atomistic banks.[2] This new

[1]When there are n oligopolistic banks, the equilibrium loan rate elasticity of demand faced by each bank is a function of n, since they take into account the effect of loan rate changes on the aggregate loan rate (see, e.g., Cetorelli and Peretto 2012; Corbae and D'Erasmo 2013). In this paper, banks internalize the effect of their decisions not only on the aggregate loan rate but also on the policy rate, thereby strategically interacting with the central bank.

[2]This result is in line with the literature that, ever since the influential empirical work of Kashyap and Stein (2000), has pointed out the importance of bank market structure in the monetary transmission mechanism.

accelerator *adds up* to the standard financial accelerator discussed in the literature on the credit channel (Bernanke and Gertler 1989; Bernanke, Gertler, and Gilchrist 1999; Kiyotaki and Moore 1997), which is also at work in our model due to the presence of borrowing-constrained agents.

More in detail, the model builds on a baseline New Keynesian model with borrowing constraints and a concentrated banking sector. The economy is populated by a small number n of intermediaries, each with a size of $1/n$, so that atomistic banks are embedded as a special case (for $n \to \infty$). Banks choose the level of their individual loan interest rate and, under perfect rationality, internalize the aggregate effects of their decisions. As an intuition, consider the case in which a (large) bank decides to increase the loan rate, with the aim of increasing its profits (the story is symmetric in the case of a reduction in the loan rate). The bank anticipates that such an increase would (proportionally) augment the aggregate interest rate on loans and, as a consequence, reduces the amount of credit that borrowers can obtain (because of the collateral constraint). Because of the credit restriction, entrepreneurs reduce investment and capital accumulation, pushing down the price of capital and the marginal cost of goods-producing firms. This effect is stronger the higher the initial leverage of the borrowers. Moreover, due to the optimal price-setting behavior in the goods market, the decline in marginal costs reduces inflation, triggering a loosening of the monetary stance proportional to the systematic response to inflation. As the policy rate in the model corresponds to the deposit rate paid to households by banks, both a higher leverage and a tougher central bank in stabilizing inflation will offer greater incentives to the bank to raise the loan rate—and thus the spread—by reducing its marginal costs to a larger extent.

The mechanism outlined in the paper bears a number of empirical implications, which constitute potential testable predictions for the model. First, the equilibrium (aggregate) level of the loan spread is positively related to the number of banks, which proxies for the level of concentration in the economy and determines the degree of strategic interaction; this effect, however, would tend to disappear for $n \to \infty$, suggesting that it should be a characteristic of highly concentrated banking markets. Many empirical works have shown that there is a positive relation between market power and the degree of concentration in banking (e.g., Bikker and Haaf 2002; Claessens and Laeven 2004, among others; see section 2 for further details). Second, the level of the spread and the degree of amplification are positively related to the level of entrepreneurs' leverage, reflecting the fact that a higher leverage implies a greater elasticity of the policy rate to changes in loan rates, which in turn increases banks' market power. Entrepreneurs' leverage (defined as the ratio of price-sensitive assets to net worth) is countercyclical in the model, as net worth tends to fall (increase) more than assets after shocks that negatively (positively) affect output. Empirical evidence overall supports the hypothesis of countercyclical firm leverage (e.g., Adrian and Shin 2010; Chugh 2009; see section 2). Third, we find that the loan spread depends on the design of the monetary policy rule. For simplicity, we limit the analysis to the simple case in which monetary policy sets the short-term interest rate based on a rule that only responds to deviations of inflation from the steady state. We find that the spread is higher the more aggressive the response to inflation, as measured by the parameter determining the systematic response in the simple rule. In addition, the inflation coefficient in the Taylor rule also interacts with the financial accelerator described above: amplification is stronger the more aggressive the central bank.

Large banks' behavior assumed in the paper is consistent with the major intermediaries' practice to regularly produce forecasts on the behavior of monetary policy. Examples can be found in research newsletters, press articles, CEO interviews, and corporate websites of the major global banks.[3] In these analyses, conditions in the

[3]For example, Deutsche Bank's *Focus Europe* newsletter regularly discusses future European Central Bank (ECB) decisions; Barclays' *Global Economics Weekly* does the same for the Bank of England, and JP Morgan's *Global Data Watch* and Bank of America–Merril Lynch's *Global Economic Weekly* do the same for the Federal Reserve. Similarly, one can easily find large bank CEOs' or other executives' interviews or website statements about future policy decisions. See, for example, for the United States, JP Morgan (http://fortune.com/2014/04/10/jamie-dimon-says-fed-stimulus-exit-will-be-easy/) and Goldman Sachs (http://blogs.wsj.com/moneybeat/2014/03/21/fed-not-seen-boosting-rates-until-2016-goldman-sachs/); for the euro zone, BNP Paribas (http://video.cnbc.com/gallery/?video=3000252516); for Sweden, Nordea (http://cbonds.it/news/item/608543); and for Switzerland, UBS (http://www.ubs.com/global/en/about_ubs/media/switzerland/releases/news-display-media-switzerland.html/en/2011/02/09/ubs_outlook_switzerland_q1_2011.html).

credit market are often mentioned as an important driver for the prospected central bank decisions. Also, the effects of monetary policy decisions on bank funding costs are sometimes explicitly considered.[4] Indeed, conditions on the credit markets *are* one of the crucial things that most central banks look at when deciding monetary policy stance.[5] In this context, it is interesting to explore, in a theoretical context, the possibility that the anticipated reaction of monetary policy weighs in the decision to change lending rates by banks that have a substantial share of the domestic credit market.[6] The rationality assumptions required in this framework are the same as those employed—as mentioned—in the literature about wage-setting behavior by non-atomistic unions (e.g., Lippi 2003; Soskice and Iversen 2000) and, more broadly, are fully consistent with the rational expectations framework.

Obviously, the existence of large and complex financial institutions not only affects competition in the banking sector. The literature assessing the influence of big banks has also focused on issues of systemic risk, interconnectedness, and "too big to fail" (e.g., Bianchi 2012). Here, we offer an alternative model for the study of large banks based on the macro literature that emerged after the recent financial crisis and that made significant progress in terms of incorporating loan spreads and studying loan-rate-setting behavior by banks (e.g., Andrés and Arce 2012; Curdia and Woodford 2010; Gerali et al. 2010). In particular, we focus on the strategic interaction between large banks and the central bank, which allows us to exploit an established theoretical framework employed for studying wage-setting behavior by non-atomistic unions (see Calmfors 2001 and Cukierman 2004 for a survey of this voluminous literature).

[4]For example, Deutsche Bank, in the June 6, 2014, issue of *Focus Europe*, proposes a quantification of the impact of the ECB's targeted LTRO auctions on the funding cost of banks from the main euro-zone countries. The estimated impact is a reduction in cost ranging between 75 basis points in Germany and 195 in Italy.

[5]Credit market conditions are regularly mentioned in the ECB's introductory statement or the Federal Open Market Committee's press release following the central banks' meetings.

[6]For example, Bank of America, Barclays, and UBS loan market shares are well above 10 percent.

Our paper is related to a number of other recent works that have studied the role of banking in business-cycle fluctuations. Christiano, Motto, and Rostagno (2010), Gertler and Karadi (2011), and Meh and Moran (2010) are among the first works to incorporate banking into general equilibrium New Keynesian models. These models feature perfect competition in banking and focus on the impact on the aggregate economy of shocks originating in the banking sector. Andrés and Arce (2012) and Olivero (2010) model competition using the Salop (1979) spatial model of horizontal product differentiation, with a finite number of banks competing in the price dimension. In their models, markups are countercyclical because the interest rate elasticity of loans is proportional to aggregate credit demand: therefore, during good (bad) times, banks lower (raise) loan rates in order to compete more aggressively and capture new borrowers. Aliaga-Díaz and Olivero (2010b) and Gerali et al. (2010) assume that banks operate in a standard regime of monopolistic competition with atomistic agents. Loan spreads are countercyclical in both models due to, respectively, switching costs for borrowers and sluggish interest rate setting by banks. Mandelman (2011) models imperfect competition by assuming that entrants must incur large sunk entry costs in highly segmented markets and incumbents adopt limit-pricing strategies (i.e., setting loan rates lower during booms) aimed at deterring entry into retail banking niches. Finally, Corbae and D'Erasmo (2013) analyze a Stackelberg environment where a small number of dominant banks choose their loan supply strategically before a large number of small banks make their loan choice. In contrast to all these papers, we model a strategic interaction between banks and the central bank. In our model, this interaction is the source of countercyclical markups and of the associated financial accelerator.

The remainder of the paper is organized as follows. Section 2 discusses theoretical and empirical evidence on the existence and the cyclical properties of loan markups. Section 3 describes the model. Section 4 shows the implications of the strategic interaction between large banks and monetary policy and its impact on the model's steady state. Section 5 illustrates the dynamic properties due to the link between the endogenous behavior of banks and the general equilibrium properties of the economy. Section 6 concludes.

2. Competition in Banking and Countercyclical Loan Markups

In this section we first provide theoretical and empirical support for our assumption about the structure of competition in the banking sector. Subsequently, we discuss evidence about the cyclical properties of bank loan markups.

2.1 Competition in Banking

One crucial assumption in the model is that banks have market power in the loan market while they operate competitively on the funding side. As regards lending, there is a wide consensus in the literature about the failure of perfect competition.[7] From a theoretical perspective, market power is often associated with the existence of switching costs. These typically arise because asymmetric information over borrowers' creditworthiness gives informational advantages to incumbent banks, generating a hold-up effect for customers and creating entry barriers for other banks (Dell'Ariccia 2001; Dell'Ariccia, Friedman, and Marquez 1999; Kim, Kliger, and Vale 2003; von Thadden 1995). Switching costs might also arise due to the presence of pure "menu costs," like costs associated with moving from one bank to another or fees incurred when applying for a loan or renegotiating the terms of an outstanding debt (Vives 2001). Other studies highlight the importance of regulatory restrictions and market contestability as a determinant of market power (Demirguc-Kunt, Laeven, and Levine 2004). The existence of market power is confirmed by a wide number of empirical analyses which, using both bank-level and aggregate data, show that most banking markets worldwide can be classified as monopolistically competitive (e.g., Bikker and Haaf 2002; Claessens and Laeven 2004; De Bandt and Davis 2000).[8]

[7]See Carletti (2008) for a comprehensive review of competition in banking, and Freixas and Rochet (2008) for a classical treatment of competition in banking.

[8]Berger et al. (2004), Claessens and Laeven (2004), and Degryse and Ongena (2008) provide extensive surveys of the empirical literature on market power in banking.

Assuming that banks' market power does not extend to the funding market (where intermediaries are competitive), we follow Aliaga-Díaz and Olivero (2010b) and Olivero (2010), in which banks price securities competitively and, at the same time, the loan market is not competitive. Asymmetric information problems vis-à-vis banks are likely to be less severe than in the loan markets, thanks to regulation and public guarantees on deposits. Competition for time and saving deposits and for wholesale funds is based on their risk-return profile, as they provide no liquidity services, unlike demand deposits (Corvoisier and Gropp 2002); these instruments must pay the same yield as instruments of comparable risk (Fama 1985). Empirical evidence is not conclusive about the impact of industry concentration on deposit rates: while most studies find a negative relation, the magnitude of the effect varies substantially across samples and specifications (Degryse and Ongena 2008).

As a by-product of the way in which we model imperfect competition in the loan market, we implicitly postulate a direct relation between the degree of concentration (proxied by the inverse of the number of banks) and market power. This assumption is consistent with the so-called structure-conduct-performance (SCP) paradigm, which predicts that competition is less intense in more concentrated markets because collusion is easier (Degryse and Ongena 2008).[9] Despite the fact that after the 1990s this paradigm evolved past this simple framework, recent empirical evidence overall supports a positive relation between concentration and market power.[10] For example, Bikker and Haaf (2002) estimate the Panzar and Rosse (1987) H-statistic for twenty-three industrialized countries over a period of roughly ten years and relate these measures to various measures of concentration (various k-bank concentration ratios, the Herfindahl

[9]It is important to note that the relation between concentration and market power in our case is relevant not because of collusion but because large banks realize that they can affect aggregate outcomes, thus exploiting the strategic interaction with the central bank.

[10]Since the 1990s, it became customary to model market structure as endogenous and measure the degree of competition via more direct measures (Berger et al. 2004). In the new paradigm, the main hypothesis is that efficiency drives the structure (efficiency-structure hypothesis), because more efficient banks will gain market share, therefore margins would be larger in more concentrated markets due to greater efficiency (e.g., Demsetz 1973).

index, and the absolute number of banks), finding evidence that higher concentration is associated with weaker competition and more market power. Claessens and Laeven (2004) reach similar conclusions for a sample of fifty countries between 1994 and 2001. Maudos and Fernandez de Guevara (2004), estimating the determinants of bank margins in the five main European countries between 1993 and 2000, find a positive effect of the Herfindahl index on bank margins, consistently with the results obtained using the Lerner index (which is a more direct measure of market power). Corvoisier and Gropp (2002) find that concentration does affect interest margins on loans.

2.2 Countercyclical Markups

A number of papers provide evidence for the existence of a negative correlation between GDP and bank markups (Angelini and Cetorelli 2003; Corbae and D'Erasmo 2013; Dueker and Thornton 1997; Mandelman 2011). A negative correlation with GDP, however, could just reflect the cyclical properties of borrowers' riskiness, which tends to increase the cost of external finance during recessions (e.g., Bernanke, Gertler, and Gilchrist 1999). Olivero (2010) provides evidence in support of a countercyclical behavior of bank cost margin *independent* of borrowers' riskiness. First, based on a large sample of bank-level data in a number of OECD countries, she shows that banks' (earned) net interest margin (a measure of bank markup which is independent of riskiness, as defaults are already accounted for) is negatively related to GDP. Second, using aggregate data from the International Monetary Fund International Financial Statistics database, she shows that a negative correlation holds for the majority of countries also when controlling for the cyclicality of credit risk in a VAR framework. In a related paper, Aliaga-Díaz and Olivero (2010a) confirm the results using quarterly Call Report data for U.S. banks between 1984 and 2005.

From a theoretical point of view, countercyclicality of bank margins (independently of credit riskiness) has been linked to the competitive structure of the banking industry. Mandelman (2011) highlights the role of entry barriers (like sunk costs). During recessions, when credit demand is low, incumbent banks may exploit their monopoly power to increase margins. During booms, however, the expansion of the financial system allows potential entrants to operate at an efficient scale, forcing incumbents to lower interest rates (and thus margins) so as to deter entry. Aliaga-Díaz and Olivero (2010b) emphasize the role of the borrower's "hold-up" effect and switching costs, which increase during recessions when borrowers' perceived riskiness increases. As a consequence, incumbent banks may charge higher interest rates, giving rise to countercyclical margins.

As a final remark, as will be explained in section 3, in the model the countercyclicality of banks' markup reflects that of firms' leverage.[11] A countercyclical behavior of leverage is consistent with a passive management of capital structure of the firm: since the market value of net worth increases in good times, and debt ratio is not actively managed, leverage would decline during expansions and increase in good times. Adrian and Shin (2010) and Chugh (2009) show that this is the case for non-financial firms in the United States, although the correlation between leverage and GDP is only mildly negative. Levy and Hennessy (2007), considering a model where all firms face financial frictions, find that also the book leverage ratio (i.e., constructed using the book rather than the market value of equity) is countercyclical for firms with less stringent constraints.

3. The Model

The economy is populated by two groups of agents of equal mass, households and entrepreneurs. Households work, consume, and save in the form of bank deposits. Entrepreneurs buy physical capital from capital goods producers, then combine that physical capital with labor to produce homogenous intermediate goods, consume, and borrow from banks. Due to the existence of financial frictions (modeled along Iacoviello 2005), lending is collateralized with physical capital. The banking sector comprises a finite number n of *large* banks, which operate in a regime of imperfect competition in the loan market and internalize the effects of their loan rate decisions on the aggregate economy.[12] In addition to entrepreneurs, there are two

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[11] As will be explained below, a higher firms' leverage increases the elasticity of the policy rate to changes in bank loan rates, generating a positive correlation with banks' markup.

[12] The way in which the banking sector is modeled is based on Gerali et al. (2010). The main departure from their framework is that we allow for fully flexible rates, and banks are assumed to be non-atomistic.

other producing sectors: retailers, who buy intermediate goods from entrepreneurs in a competitive market, differentiate and price them subject to nominal rigidities, and resell them with a markup over marginal cost; and capital goods producers, who are introduced so as to derive a market price for capital. Monetary policy is conducted according to a simple rule, whereby the (gross) nominal interest rate is set in response to endogenous variations in (gross) inflation ($\pi_t \equiv P_t/P_{t-1}$), as follows:

$$R_t^{ib} = R^{ib} \pi_t^{\phi_\pi} \exp(\varepsilon_t^{R^{ib}}), \qquad \phi_\pi \geq 0, \tag{1}$$

where R_t^{ib} is the gross nominal interest rate, R^{ib} is the steady-state level of R_t^{ib}, and $\varepsilon_t^{R^{ib}}$ is a (white noise) monetary policy innovation with zero mean and variance $\varsigma^{R^{ib}}$.

3.1 Households and Entrepreneurs

Household h solves the following problem:

$$\max_{\left\{c_t^P(h),\ l_t^P(h),\ d_t^P(h)\right\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_P^t \left[\log(c_t^P(h)) - \frac{l_t^P(h)^{1+\phi}}{1+\phi}\right] \tag{2}$$

subject to the budget constraint:

$$c_t^P(h) + d_t^P(h) \leq w_t l_t^P(h) + R_{t-1}^{ib} d_{t-1}^P(h) + J_t^f(h) + J_{t-1}^b(h), \tag{3}$$

where $c_t^P(h)$ is current consumption; $d_t^P(h)$ is bank deposits in real terms, which are remunerated at a rate equal to the policy rate R_t^{ib}; w_t is real wage; $l_t^P(h)$ is labor supply; and $J_t^f(h)$ and $J_{t-1}^b(h)$ are the real (lump-sum) profits, respectively, by the retailers and by the banks.[13] The parameters ϕ and β_P denote the inverse of the Frisch labor supply elasticity and the households' discount factor.

[13] Though it is not critical to our central message here, credits and debts are assumed to be indexed to current inflation; this removes the so-called nominal credit/debt channel from the model. This channel, which implies that changes in the price level have real effects on the aggregate economy because they redistribute real resources between borrowers and lenders, is quite important in Gerali et al. (2010) and in many papers with a collateral channel (e.g., Iacoviello 2005); however, it is possible to show that introducing the nominal credit/debt channel would not affect the key strategic mechanisms at work in this paper.

The relevant first-order conditions are the Euler equation

$$\frac{1}{c_t^P(h)} = \beta_P \mathbb{E}_t \frac{R_t^{ib}}{c_{t+1}^P(h)} \tag{4}$$

and the labor-supply decision

$$l_t^P(h)^\phi = \frac{w_t}{c_t^P(h)}. \tag{5}$$

There is a continuum of measure one of entrepreneurs indexed by $i \in [0, 1]$. Entrepreneurs' optimization problem is given by

$$\max_{\left\{c_t^E(i),\ k_t^E(i),\ b_t^E(i)\right\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_E^t \log(c_t^E(i)) \tag{6}$$

subject to a budget and a borrowing constraint, respectively:

$$\begin{aligned} c_t^E(i) + R_{t-1}^b b_{t-1}^E(i) + w_t l_t(i) + q_t^k k_t^E(i) \\ \leq \frac{y_t^E(i)}{x_t} + b_t^E(i) + q_t^k(1-\delta^k)k_{t-1}^E(i), \end{aligned} \tag{7}$$

$$R_t^b b_t^E(i) \leq \mathbb{E}_t m^E q_{t+1}^k k_t^E(i)(1-\delta^k). \tag{8}$$

In the equations above, $c_t^E(i)$ is entrepreneurs' consumption, $b_t^E(i)$ is the amount of borrowing from banks, R_t^b is the (gross) aggregate interest rate on loans, w_t is real wage, $l_t(i)$ is labor demand, $k_t^E(i)$ is entrepreneurs' stock of capital, q_t^k is the price of capital, y_t^E is the output of intermediate goods produced by the entrepreneurs, x_t is the markup of the retailer sector, and δ^k is the depreciation rate of capital. In the borrowing constraint, m^E is a parameter that can be interpreted as the loan-to-value (LTV) ratio chosen by the banks (i.e., the ratio between the amount of loans issued and the discounted next-period value of entrepreneurs' assets). The parameter β_E is the entrepreneurs' discount factor. As is standard in models with a borrowing constraint, we assume that $\beta_E < \beta_P$.

Production is carried out using the following Cobb-Douglas technology:

$$y_t^E(i) = A_t^E(k_{t-1}^E(i))^\alpha(l_t(i))^{1-\alpha}, \tag{9}$$

where A_t^E is a productivity shock to the neutral technology. The shock follows the process $\log(A_t^E) = \log(A^E) + \varepsilon_t^{A^E}$, where $\varepsilon_t^{A^E}$ is white noise with zero mean and variance ς^{A^E}.

Entrepreneurs' demand for loans is derived as in Gerali et al. (2010). We assume that an entrepreneur seeking an amount of loans $b_t^E(i)$ has to purchase a composite basket of slightly differentiated financial products, supplied by n banks, with elasticity of substitution equal to ϵ^b (with $\epsilon^b > 1$). This constraint can be expressed as

$$b_t^E(i) = \left[\int_0^1 b_t^E(i,j)^{\frac{\epsilon^b - 1}{\epsilon^b}} \mathrm{d}j\right]^{\frac{\epsilon^b}{\epsilon^b - 1}}. \tag{10}$$

Let $\int_0^1 R_t^b(j) b_t^E(i,j)\mathrm{d}j$ denote the total repayment due to the continuum of financial products demanded by entrepreneur i. Demand for real loans $b_t^E(i)$ from entrepreneur i is obtained by minimizing the total repayment over $b_t^E(i,j)$, subject to the constraint (10). Cost minimization implies the set of demand schedules $b_t^E(i,j) = \left(\frac{R_t^b(j)}{R_t^b}\right)^{-\epsilon^b} b_t(i)^E$, for all $i \in [0,1]$ and $j \in [0,1]$. Integrating the latter across entrepreneurs yields the total demand for loans of type j

$$b_t^E(j) = \left(\frac{R_t^b(j)}{R_t^b}\right)^{-\epsilon^b} b_t^E; \qquad b_t^E = \int_0^1 b_t(i)^E \mathrm{d}i, \tag{11}$$

where R_t^b is defined as

$$R_t^b = \left[\int_0^1 R_t^b(j)^{1-\epsilon^b} \mathrm{d}j\right]^{\frac{1}{1-\epsilon^b}}. \tag{12}$$

For the sake of simplicity, I assume that loan demands are equally distributed across banks so that each entrepreneur demands $1/n$ loan types to the same bank.

The maximization of problem (6) yields the following first-order conditions:

$$\lambda_t^E = 1/c_t^E \tag{13}$$

$$\lambda_t^E - \beta_E \mathbb{E}_t R_t^b \lambda_{t+1}^E = \lambda_t^E s_t^E, \tag{14}$$

$$\lambda_t^E s_t^E m^E \mathbb{E}_t \frac{q_{t+1}^k (1-\delta^k)}{R_t^b} + \beta_E \mathbb{E}_t \lambda_{t+1}^E [q_{t+1}^k (1-\delta^k) + r_{t+1}^k] = q_t^k \lambda_t^E, \tag{15}$$

$$w_t = (1-\alpha) \frac{y_t^E}{l_t x_t}, \tag{16}$$

$$r_t^k = \alpha \frac{y_t^E}{k_{t-1}^E x_t}, \tag{17}$$

where λ_t^E and $\lambda_t^E s_t^E$ are multipliers on the constraints (7) and (8), respectively, and r_t^k is the rental rate of physical capital.

The intertemporal choice of an entrepreneur (14) is distorted when the credit constraint is binding, i.e., when $s_t^E > 0$. Under our assumptions about the agents' discount factors and because of the existence of a positive markup between the loan and the policy rate, this is always the case in a neighborhood of the steady state.[14] As a result, in equilibrium, households are net lenders and entrepreneurs are net borrowers.

Equation (15) equates the marginal cost of one unit of capital $q_t^k \lambda_t^E$ to its (expected discounted) marginal benefit. The latter has three components: (i) the expected future price of capital, since capital acquired today can be resold tomorrow to the capital sector at $q_{t+1}^k(1-\delta^k)$; (ii) the return on capital used in the production, r_{t+1}^k; (iii) the shadow value of borrowing, since capital acquired today can be used as collateral in borrowing.

Following Andrés, Arce, and Thomas (2013), we can define entrepreneurs' net worth as follows:[15]

$$nw_t^E \equiv r_t^k k_{t-1}^E + q_t^k \left(1-\delta^k\right) k_{t-1}^E - R_{t-1}^b b_{t-1}^E. \tag{18}$$

[14]In particular, the households' and the entrepreneurs' Euler equations (4) and (14), evaluated at the steady state, are equal to, respectively, $1 = \beta_P R^{ib}$ and $1 - \beta_E R^b = s^E$. Therefore, $s_t^E > 0$ if $\beta_P R^{ib} - \beta_E R^b > 0$. This is the case if $\beta_P/\beta_E > \mathcal{M}^b \equiv R^b/R^{ib}$. As will be shown in section 4, this holds given our baseline calibration.

[15]Defining net worth nw_t^E is convenient also for illustrating the timing of the model. At the end of (any given) period t, (i) entrepreneurs hold nw_t^E; (ii) banks lend b_t^E to entrepreneurs to purchase new capital $q_t^k k_t^E$. At the beginning of period $t+1$, entrepreneurs (i) produce using k_t^E units of capital and obtain a unit return of r_{t+1}^k after paying wages to patient workers; (ii) sell $q_{t+1}^k(1-\delta^k)k_t^E$ to the capital sector; (iii) pay back $R_t^b b_t^E$ to banks. Thus, in equation (18),

Substituting (18) into (15) and (14), we can rewrite entrepreneurs' aggregate consumption, c_t^E, and capital in the next period, k_t^E, as a constant fraction of nw_t^E (see appendix 1 for the derivation of the equations):

$$c_t^E = (1-\beta_E)\, nw_t^E. \tag{19}$$

$$q_t^k k_t^E = \frac{\beta_E}{1 - b_t^E/(q_t^k k_t^E)} nw_t^E. \tag{20}$$

Before turning to the derivation of the optimal loan interest rate, it is convenient to define the entrepreneurs' debt-to-capital ratio,

$$V_t^E \equiv \frac{b_t^E}{q_t^k k_t^E} \tag{21}$$

and the gross expected change of capital price,

$$\Delta_{t+1} \equiv \mathbb{E}_t q_{t+1}^k / q_t^k. \tag{22}$$

From equation (20) we derive the following relation between the debt-to-capital ratio and the entrepreneurs' leverage (LV_t^E):

$$LV_t^E \equiv \frac{q_t^k k_t^E}{nw_t^E} = \frac{\beta_E}{1 - V_t^E}. \tag{23}$$

3.2 Retailers and Capital Goods Producers

As is standard in this class of models, we assume that there exists another group of agents, the *retailers*, who buy the intermediate goods from entrepreneurs in a competitive market, brand them at no cost, and sell the differentiated good at a price that includes a markup over the purchasing cost.[16] The introduction of retailers is useful for introducing nominal rigidities. In particular, in our model

$r_t^k k_{t-1}^E + q_t^k(1-\delta^k)k_{t-1}^E$ denotes the entrepreneur's gross capital return at time t, while $R_{t-1}^b b_{t-1}^E$ is the effective cost of borrowing.

[16] For example, Bernanke, Gertler, and Gilchrist (1999) and Gerali et al. (2010) use the same modeling device.

we assume that retailers face a quadratic adjustment cost parameterized by κ_p whenever they want to change their price (Rotemberg 1982). In particular, retailers maximize the following profit function:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^{P} \left[P_t(i) y_t^E(i) - P_t^W y_t^E(i) - \frac{\kappa_p}{2} \left(\frac{P_t(i)}{P_{t-1}(i)} - 1 \right)^2 P_t y_t^E \right] \tag{24}$$

subject to the demand derived from consumers' maximization,

$$y_t^E(i) = (P_t(i)/P_t)^{-\epsilon^y} y_t^E,$$

where $\epsilon^y > 1$ denotes the elasticity of substitution across brand types, $\Lambda_{0,t} \equiv \beta_P c_0^P / c_t^P$ is the households' stochastic discount factor, c_t^P is current consumption, and $y_t = (\int_0^1 y_t(i)^{(\epsilon^y - 1)/\epsilon^y} \mathrm{d}j)^{\epsilon^y/(\epsilon^y - 1)}$.

The first-order conditions for $P_t(i)$ yields the familiar New Keynesian Phillips curve:

$$\begin{aligned} 1 - \frac{mk^y}{mk^y - 1} + \frac{mk^y}{mk^y - 1} mc_t^E - \kappa_p(\pi_t - 1)\pi_t \\ + \beta_P \mathbb{E}_t \left[\frac{c_t^P}{c_{t+1}^P} \kappa_p (\pi_{t+1} - 1)\pi_{t+1} \frac{y_{t+1}^E}{y_t^E} \right] = 0, \end{aligned} \tag{25}$$

where $mk^y \equiv \epsilon^y/(\epsilon^y - 1)$, $mc_t^E = 1/x_t$ is the real marginal cost, and $x_t \equiv P_t/P_t^W$.

In addition, we assume that fixed capital creation is carried out by *capital goods producers* (CGPs) and is subject to some adjustment costs. CGPs operate in a perfectly competitive environment. They buy last-period undepreciated capital $((1-\delta^k)k_{t-1}^E)$ from entrepreneurs at (a nominal) price Q_t^k, and I_t units of final goods from retailers at price P_t. Using these inputs, CGPs increase the stock of effective capital $\bar{z}$, which is then sold back to entrepreneurs at the same price, Q_t^k. Old capital can be converted one-to-one into new capital, while the transformation of the final good is subject to quadratic adjustment costs. CGPs therefore choose $\bar{z}_t$ and I_t so as to maximize

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^{E} (q_t^k \Delta \bar{z}_t - I_t) \tag{26}$$

subject to

$$\bar{z}_t = \bar{z}_{t-1} + \left[1 - \frac{\kappa_i}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right] I_t, \tag{27}$$

where $q_t^k \equiv Q_t^k/P_t$ is the real price of capital, $\Lambda_{0,t}^E \equiv \beta_E c_0^E/c_t^E$ is the entrepreneurs' stochastic discount factor, and c_t^E is the current consumption. The first-order condition is

$$1 = q_t^k \left[1 - \frac{\kappa_i}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 - \kappa_i\left(\frac{I_t}{I_{t-1}} - 1\right)\frac{I_t}{I_{t-1}}\right] + \beta_E \mathbb{E}_t\left[\frac{c_t^E}{c_{t+1}^E} q_{t+1}^k \kappa_i \left(\frac{I_{t+1}}{I_t} - 1\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right]. \tag{28}$$

3.3 Banks

The economy is populated by a finite number n of banks (with $n \geq 2$), which collect time deposits from households and issue loans to entrepreneurs. We assume that the deposit market is perfectly competitive while (as mentioned above) the loan market is modeled along Gerali et al. (2010), with a Dixit-Stiglitz type of competition.[17]

Before lending funds to entrepreneurs, each bank observes the entrepreneur's net wealth (18) and takes it as given. Loan types are equally distributed across banks, so that each bank has a share of total loans equal to $1/n$. In other words, $1/n$ can be interpreted as the degree of concentration in the credit market. Loan interest rates are fully flexible and set independently and simultaneously. We assume that each large bank takes as given the loan rates set by the other banks and the effects of loan rate on variables in the

[17] As discussed in section 2, this hypothesis is consistent with previous literature and is justified on theoretical grounds. Assuming the existence of market power also in the deposit market, our results on bank margin (defined as the difference between the rate on loans and deposits) would be reinforced. In that case, the interest rate on deposits would be set as a markdown over the policy rate. Due to the strategic interaction, symmetrically to the case of the rate on loans, the large banks would have an incentive to set the deposit rate below the level set by atomistic banks. The intuition is that this would boost household consumption, aggregate demand, and inflation, thus prompting an increase of the policy rate.

next period. In the interaction with the central bank (and the rest of the economy), banks internalize the general equilibrium effects of their loan rates at time t. In particular, the representative bank u (where $u \in \{1, \ldots, n \geq 2)$ sets the same interest rate $R_t^b(u)$ on all loans provided to entrepreneurs $j \in u$ so as to maximize profits:[18]

$$J_t^b = \int_{j \in u} \left[R_t^b(j) - R_t^{ib}\right] b_t^E(j) \mathrm{d}j \tag{29}$$

subject to the loan demand (11), the budget constraints (3) and (7), the borrowing constraint (8), the New Keynesian Phillips curve (25), the equilibrium condition for the labor market (obtained by combining the labor demand (16) with the households' first-order conditions (4) and (5)),[19] and the interest rate rule (1).

The solution to the banks' problem reads

$$R_t^b = \frac{\epsilon^b(n-1) + \Sigma_{b,t} + \Sigma_{R^{ib},t}}{\epsilon^b(n-1) + \Sigma_{b,t} - n} R_t^{ib} \equiv \mathcal{M}_t^b R_t^{ib}, \tag{30}$$

where $\Sigma_{b,t}$ and $\Sigma_{R^{ib},t}$ are, respectively, the elasticity (in absolute value) of aggregate loans, b_t^E, and the elasticity of policy interest rate, R_t^{ib}, to the aggregate loan rate, R_t^b.

The first-order condition (30) is the key equation for our results.[20] It shows that banks set the loan interest rate as a markup ($\mathcal{M}_t^b$) over the policy interest rate. In standard models with monopolistic competition, this markup (and thus the loan rate) is typically time invariant and depends only on the elasticity of substitution among varieties. In this case, instead, due to the assumption of non-atomistic banks, it depends on the number of banks in the economy and is time varying, according to the elasticities of aggregate loans and of the policy rate to the aggregate loan rate.

[18]For the sake of simplicity, we assume an exogenous distribution of symmetric banks. Corbae and D'Erasmo (2013) focus instead on heterogeneity across the bank size distribution.

[19]In particular, the condition is

$$(1-\alpha) y_t^E(i) mc_t \beta_P \mathbb{E}_t \frac{R_t^{ib}}{c_{t+1}^P(i)} = \left[l_t^P(i)\right]^{1+\phi}.$$

[20]For a complete derivation of this expression and of its components, see appendix 2.

The reason why $\mathcal{M}_t^b$ is endogenously determined by n, $\Sigma_{b,t}$, and $\Sigma_{R^{ib},t}$ is the strategic interaction that the presence of large banks induces among banks and between banks and the central bank.

The number of banks n is relevant because the size of banks is inversely proportional to their number. In turn, the bank's size determines the impact of a change in bank u's loan rate on the aggregate loan rate R_t^b (as shown in appendix 2) by

$$\frac{\partial R_t^b}{\partial R_t^b(u)} = \frac{1}{n}. \tag{31}$$

Note that when bank size tends to zero—i.e., n tends to infinity—the effect of the strategic interaction disappears and the markup converges to the value it assumes in standard models of monopolistic competition:

$$\lim_{n \to \infty} \mathcal{M}_t^b = \frac{\epsilon^b}{\epsilon^b - 1}. \tag{32}$$

$\Sigma_{b,t}$ and $\Sigma_{R^{ib},t}$ appear in the expression of the markup because they affect the incentives of the banks to strategically change the loan rate, which in turn depend on the impact that such changes have on the different components of bank profits (29): loan demand b_t^E and the cost of deposits R_t^{ib}. To understand the intuition, consider the case of an increase in the loan rate (a symmetric argument could be used for the case of reduction in the loan rate). When credit constraints are binding, the increase in R_t^b reduces entrepreneurs' borrowing, according to equation (8). In turn, the reduction in loans lowers banks' profits (for given levels of the interest rates), thus reducing the incentive to increase the interest rate in the first place. The intensity of the reduction in borrowing is proportional to $\Sigma_{b,t}$, which is therefore negatively related to $\mathcal{M}_t^b$. The algebraic expression for $\Sigma_{b,t}$ reveals that, in turn, the intensity of loan reduction is proportional to the level of firms' leverage (as implied by the borrowing constraint):

$$\Sigma_{b,t} \equiv -\frac{\partial b_t^E}{\partial R_t^b}\frac{R_t^b}{b_t^E} = 1 + \Sigma_{LV,t}, \tag{33}$$

where

$$\Sigma_{LV,t} \equiv -\frac{\partial LV_t^E}{\partial R_t^b}\frac{R_t^b}{LV_t^E} = \frac{LV_t^E}{\beta_E} - 1 \tag{34}$$

denotes the elasticity of entrepreneurs' leverage (23) to the aggregate loan rate R_t^b.

The relation between the markup $\mathcal{M}_t^b$ and $\Sigma_{R^{ib},t}$ is somewhat less direct and relies on the impact that a rise in the loan rate has on aggregate demand, via the reduction in borrowing. Indeed, as (borrowers') leverage reduces, entrepreneurs are forced to reduce capital expenditure (through (20)) and consumption. The fall in aggregate demand puts downward pressure on marginal costs and on inflation (via the Phillips curve (25)), prompting a response by the central bank which, as mentioned, is assumed to follow a simple rule targeting deviations of inflation from its (zero) steady state. Banks anticipate that the ensuing cut in the policy rate will lower their financing cost, offering incentives to increase the loan rate in the first place.[21] This effect is proportional to $\Sigma_{R^{ib},t}$, which therefore displays a positive correlation with the bank's markup. The expression for $\Sigma_{R^{ib},t}$ is

$$\begin{aligned}\Sigma_{R^{ib},t} &\equiv -\frac{\partial R_t^{ib}}{\partial R_t^b}\frac{R_t^b}{R_t^{ib}}\\ &= \frac{q_t^k k_t^E mc_t \phi_\pi}{c_t^P \phi_\pi mc_t + y_t^E \Psi[(mk^y - 1)\kappa_p + mk^y mc_t \phi_\pi]}\Sigma_{LV,t},\end{aligned} \tag{35}$$

where $\Psi \equiv (1-\alpha)/[mk^y(\alpha+\phi)]$.

Two things are worth stressing. First, borrowers' leverage plays a significant role also in this case: the elasticity of the policy rate is positively correlated with LV_t^E, reflecting the fact that—other things being equal—the fall in aggregate demand and the ensuing policy response is stronger the higher entrepreneurs' leverage. Second, $\Sigma_{R^b,t}$ also depends on the central bank's inflation coefficient ϕ_π, which determines the intensity of monetary policy response for

[21]This is reminiscent of results obtained in the non-atomistic wage setter literature. For a description of the main strategic effects analyzed in this strand of literature in open and closed economies, see Cuciniello (2011).

a given reduction in aggregate inflation. This result underscores the potential importance of the strategic interaction between large banks and the central bank. In particular, it shows how the design of monetary policy may interact with market power in the banking sector and have an impact on banks' interest rate decisions.[22]

Of course, the mechanism described in this section depends on the assumption that bank profits in our model coincide with the interest rate margin.[23] Moreover, the results about the cyclical properties of profits hinge on the fact that, in the case of an increase in bank loan rates (and symmetrically for a decrease), the fall in the amount of intermediated funds does not compensate the positive impact on the unit interest margin. As shown in section 2, this is consistent with the empirical behavior of bank price-cost margins. In the real world, bank profit-and-loss statements obviously include many other items, such as trading and other non-interest income, operating costs, and loan loss provisions.[24]

4. The Steady State

What are the implications of the mechanism described in the previous section? After discussing the model baseline calibration, we first provide an analysis of the steady-state properties of the model. In the next section, we focus on the dynamic properties of the model with large banks.

Table 1 reports the calibration of the main parameters in the model. The households' discount factor β_P is set at 0.996, which implies a steady-state policy rate of roughly 2 percent (annualized). The entrepreneurs' discount factor β_E has to be smaller than β_P and is set at 0.97, as in Iacoviello (2005).[25] The inverse of the Frisch

[22] As mentioned in the introduction, here we limit the analysis to the interaction between large banks and monetary policy, which is certainly easier to understand. Our framework could, however, be extended to study the interaction with other types of policies, such as credit or macroprudential policy, which could deliver additional interesting results.

[23] See equation (29).

[24] Indeed, if one considers overall bank profits, empirical evidence suggests that they are procyclical (Albertazzi and Gambacorta 2009).

[25] Given this calibration, $\beta_P/\beta_E = 1.02680$, while $\mathcal{M}^b$ ranges between 1.006 (for the case of atomistic banks) and 1.02676 (for the case with $n = 3$). This guarantees that the collateral constraint is binding in the steady state (see footnote 14).

Table 1. Baseline Calibration

	Value	Description
β_P	0.996	Household Discount Factor
β_E	0.97	Entrepreneurial Discount Factor
ϕ	1	Inverse Frisch Elasticity of Labor Supply
α	0.30	Product Elasticity with Respect to Physical Capital
m^E	0.80	Entrepreneurs' LTV Ratio
ϵ^b	161	Elasticity of Substitution of Loans
ϵ^y	6	Elasticity of Substitution of Goods
κ_p	30	Price Stickiness
κ_i	0.4	Investment Adjustment Cost
δ^k	0.01	Depreciation Rate of Physical Capital
ζ^{A^E}	0.01	TFP Standard Deviation Innovation
$\zeta^{R^{ib}}$	0.0025	Monetary Policy Standard Deviation Innovation
ϕ_π	1.5	Strength of Monetary Policy Response to Inflation

elasticity ϕ is set at 1 (Galí 2008). The share of capital in the production function (α) and the depreciation rate of physical capital (δ^k) are set at 0.30 and 0.01, respectively. These values imply that the investment-to-GDP ratio and the entrepreneurs' share in consumption equal 0.13 and 0.09, respectively, similar to Gerali et al. (2010). The parameter governing the investment adjustment cost (κ^i) is set at 0.4 so as to obtain an impact response of asset prices after the shocks considered similar in magnitude to the one in Gerali et al. (2010), where it roughly moves one-to-one with GDP. The degree of price stickiness κ_p is set at 30, corresponding to a Calvo probability of not being able to adjust prices of roughly 66 percent, which implies that adjustment occurs, on average, every three quarters. The elasticity of substitution across goods ϵ^y is set at 6, implying a markup in the goods market of 20 percent. In the Taylor rule, the baseline calibration for the strength of monetary policy response to inflation ϕ_π is set at 1.5.

As regards the parameters related to the financial frictions and the banking sector, we set the LTV ratio m^E at 0.80. This implies that the steady-state debt-to-GDP ratio (at an annual frequency) is equal to 2.5, in line with the average private-sector debt-to-GDP ratio in Europe over the last five years. The debt-to-asset ratio is 0.79, which corresponds to the non-financial private-sector indebtedness of euro-area countries measured as a percentage of financial assets. The elasticity of substitution across loan varieties ϵ^b (which contributes to determining the steady-state loan spread) is set at 161, which implies, in the case of atomistic banks, a steady-state gross markup $\mathcal{M}^b$ of 1.006. This value, in turn, corresponds to a net spread between the loan rate and the policy rate of around 2.5 percentage points in annual terms.[26]

The non-stochastic steady state of the model is derived by setting the shocks to their mean value and assuming a gross inflation rate equal to one. The technology parameter A^E is normalized so that $y^E = 1$. In the zero-inflation steady state, the Phillips curve (25) implies that $mc = 1/mk^y$. From equation (28), the steady-state price of capital, q^k, equals 1. As usual, in the steady state, $R^{ib} = 1/\beta_P$. The steady-state values of R^b, c^P, k^E, and LV^E are obtained by solving simultaneously for the equations below (see appendix 3 for the derivation):

$$R^b = \mathcal{M}^b/\beta_P, \tag{36}$$

$$c^P = 1 - \frac{\alpha(1-\beta_E+\delta^k LV^E)}{[1-(1-\delta^k)LV^E(1-m^E)]mk^y} \tag{37}$$

$$k^E = \frac{\alpha LV^E}{[1-(1-\delta^k)LV^E(1-m^E)]mk^y} \tag{38}$$

$$LV^E = \frac{\beta_E R^b}{R^b-(1-m^E)\delta^k}, \tag{39}$$

where the markup in equation (36) is given by

$$\mathcal{M}^b = \frac{\epsilon^b(n-1)+\Sigma_b+\Sigma_{R^{ib}}}{\epsilon^b(n-1)+\Sigma_b-n} > 1, \tag{40}$$

and

$$\Sigma_{R^{ib}} = \frac{k^E mc\phi_\pi}{c^P\phi_\pi mc + \Psi[(mk^y-1)\kappa_p+\phi_\pi]}\left[\frac{LV^E}{\beta_E}-1\right] \tag{41}$$

$$\Sigma_b = LV^E/\beta_E. \tag{42}$$

[26]In particular, the gross (quarterly) policy rate is $R^{ib} = 1/\beta_p = 1.004$ and the gross loan rate is $R^b = R^{ib}\mathcal{M}^b = 1.01004$. The net annualized spread is therefore $400(R^b - R^{ib}) \simeq 2.4$ percentage points.

Figure 1. Relation between Bank Markup and Entrepreneurs' Leverage, for Different Values of the Number of Banks Operating in the Loan Market

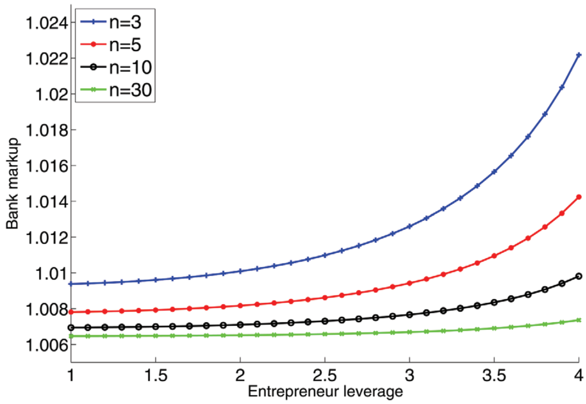
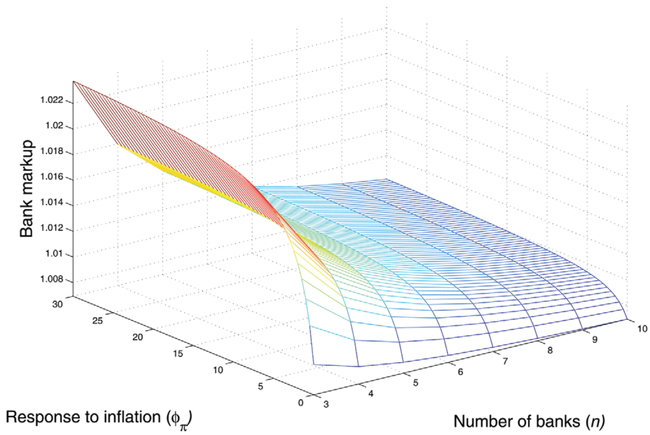


Figure 1 depicts graphically the relation between the steady-state level of the markup and the level of entrepreneurs' leverage (LV^E), under different assumptions regarding the number of banks. In particular, we study the cases in which the number of banks operating in the market equals three (line with + symbols), five (line with closed circles), ten (line with open circles), and thirty (light grey line).

A number of considerations are in order. First, the markup is positively related to the level of borrowers' leverage. In the previous section we commented how the effect of LV^E on $\mathcal{M}^b$ was in principle ambiguous, as it was positively related with both Σ_b and $\Sigma_{R^{ib}}$, which had opposite effects on the markup. The graphical result suggests that, in our calibration, the impact of LV^E on $\Sigma_{R^{ib}}$ prevails. Second, as the number of banks grows, $\mathcal{M}^b$ decreases—for any given value of LV^E—gradually converging to 1.006, which corresponds to the value of $\frac{\epsilon^b}{\epsilon^b-1}$, that is, the value of the markup with atomistic banks. Moreover, as n increases, the positive relation with leverage also disappears, in line with the irrelevance of strategic interactions.

Figure 2 shows the relation among ϕ_π, n, and the bank's markup $\mathcal{M}^b$ in a tridimensional plot (with the remaining parameters still

Figure 2. Relation between Bank Markup, Degree of Monetary Policy Aggressiveness towards Inflation, and Number of Banks Operating in the Loan Market

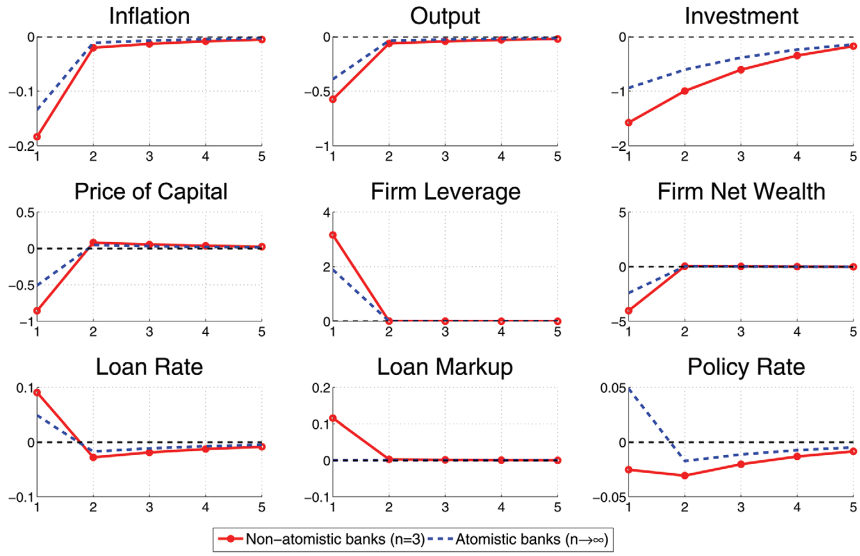


calibrated as in table 1). The value of entrepreneurs' leverage underlying the figure is 3. In this case, we note that the degree of central bank's inflation coefficient is positively related to the markup. Also in this case, note that this result holds as long as the number of banks is not too big (and therefore their size is non-negligible): symmetrically to the previous figure, as n grows, the association between ϕ_π and the markup weakens, with the latter converging to $\frac{\epsilon^b}{\epsilon^b-1} = 1.006$. These results underline a potential trade-off for the central bank regarding the choice of the appropriate degree of aggressiveness towards inflation: a higher ϕ_π stabilizes inflation to a larger extent, but it induces an increase in the degree of monopolistic power of banks in the long run.

5. The Financial Acceleration Markup and the Propagation of Shocks

We now turn to studying the dynamic responses of the model to a monetary shock and a technology shock, showing the impact of different calibrations for n and ϕ_π. We again refer to table 1 for the calibration of the other parameters. Since n and ϕ_π affect the steady state of the model, in the simulations we assume the existence of a

Figure 3. Impulse Response to a One-Standard-Deviation Contractionary Monetary Shock (percent deviation from steady state)



Notes: The figure compares the models with atomistic and large banks.

subsidy Υ (financed with a lump-sum tax) that fully offsets the effect of monopolistic competition in the banking sector, i.e., $\mathcal{M}^b/(1+\Upsilon)=1$, thus generating identical steady states in all models.[27]

We set the serial correlation of the technological and monetary shock equal to zero to help us understand the mechanisms at play. Figure 3 reports the response to a temporary monetary restriction (defined as a shock to $\varepsilon_t^{R^{ib}}$ in equation (1)), calibrating the inflation coefficient ϕ_π at 1.5. The dashed lines correspond to the case of atomistic banks, while the solid lines with circles correspond to the case of large banks with a loan market share of around 30 percent, i.e., $n = 3$.

[27]Note that, given the existence of this subsidy, in contrast to footnote 14, the condition $\beta_P > \beta_E$ is sufficient to guarantee that the borrowing constraint is always binding, similarly to Iacoviello (2005).

Qualitatively, the response of the main variables is similar in the two cases. Following the shock, inflation and output drop, reflecting the contraction in consumption and the fall in investment. The price of capital and entrepreneurs' borrowing also fall. Entrepreneurs' leverage, however, increases as net wealth is hit more severely than the reduction in borrowing. This negative correlation between leverage and output is consistent with a passive management of capital structure of the firm and with the findings in Adrian and Shin (2010), Chugh (2009), and Levy and Hennessy (2007) (see section 2).

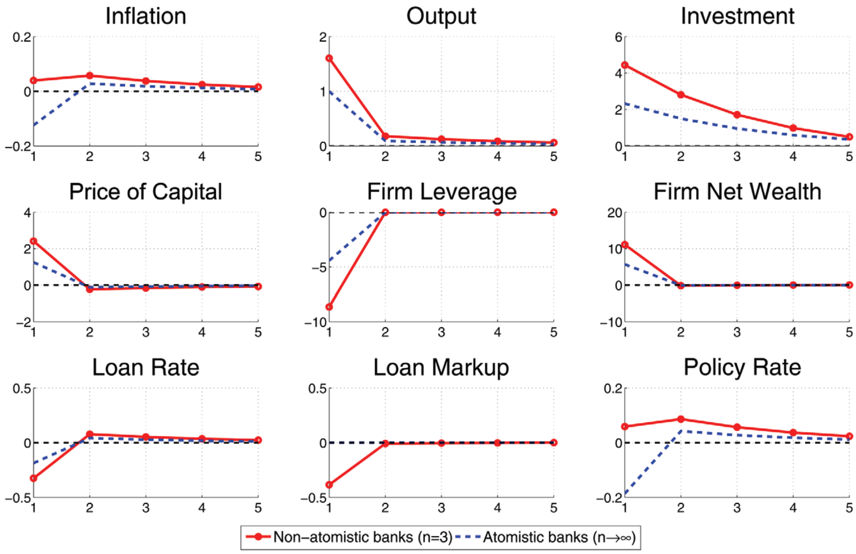
The presence of non-atomistic players, however, makes a significant quantitative difference. In this case, banks' markup is positively related to leverage and therefore increases following the contractionary shock. When banks are atomistic, there is a one-to-one relationship between changes in the loan rate and changes in the policy rate, as the markup is constant. As a consequence of the increase in the markup, the negative dynamics in the model get amplified, bringing about a stronger contraction in output.

This mechanism unveils the existence, in this context, of a new type of *financial accelerator*, which is crucially related to the presence of large banks. This mechanism is different in nature to the standard financial accelerator discussed in the literature on the credit channel (Bernanke and Gertler 1989; Bernanke, Gertler, and Gilchrist 1999; Kiyotaki and Moore 1997) and *adds up* to that channel, which is also at work in the model due to the presence of borrowing-constrained agents.

Figure 4 displays the response of the model to a positive productivity shock (see equation (9)), again comparing the case of atomistic banks and large banks. Also in this case, the presence of non-atomistic banks operates as an amplification mechanism of the fluctuations in the real variables. The size of the response of output and asset prices is roughly twice as large as in the case of atomistic banks. Again, the explanation is that the presence of large banks implies a countercyclical movement in banks' markup, which brings about (in the case considered) a stronger reduction in the loan interest rate. In addition, under our calibration the amplification effect on the demand size is such that inflation turns out to be positive with large banks.

In the previous two exercises, we kept the value of the central bank's inflation coefficient ϕ_π fixed at 1.5. However, as we noted

Figure 4. Impulse Response to a One-Standard-Deviation Expansionary Technology Shock (percent deviation from steady state)

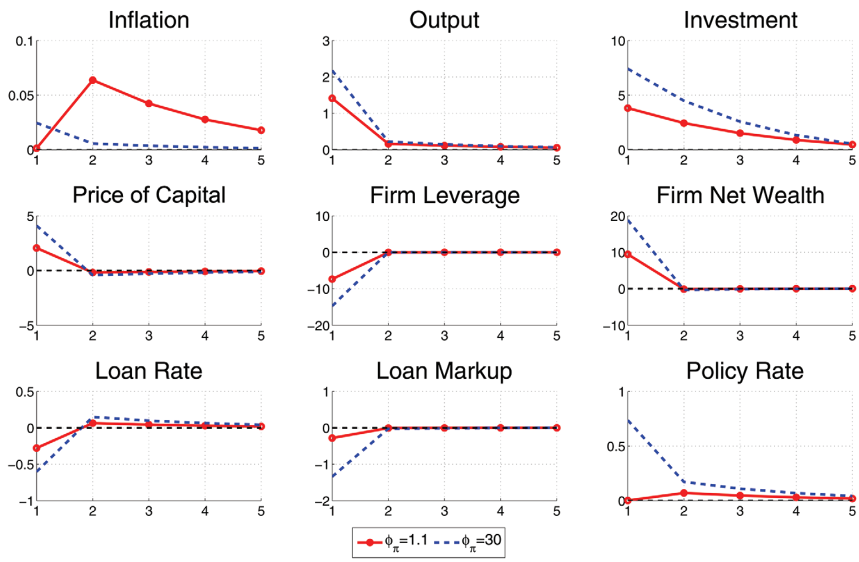


Notes: The figure compares the models with atomistic and large banks.

in section 3, the value of this parameter also has an impact on the dynamic response of the model to the shocks. Figure 5 compares, for the case of non-atomistic banks ($n = 3$), the response of the model to a positive technology shock assuming two different values of the central banks' inflation coefficient: (i) $\phi_\pi = 30$, which can be considered as the (extreme) case of monetary policy following a very strict inflation targeting,[28] and (ii) $\phi_\pi = 1.1$, that is, the case of a "weak" inflation coefficient. The figure shows that the (countercyclical) response of the markup is substantially stronger in the case of the aggressive inflation response. In turn, the increase in output, investment, and asset prices is also more pronounced.

[28]Results are qualitatively similar also assuming more realistic—though still high—values for ϕ_π, like 3 or 5.

Figure 5. Effect of Different Inflation Coefficients with a Positive Technological Shock and $n = 3$ (percent deviation from steady state)



6. Conclusions

In this paper we build a New Keynesian model with financial frictions and large banks, i.e., intermediaries that internalize the aggregate effects of their individual loan-pricing decisions. In the model, due to the strategic interactions between the large banks and the central bank, the bank loan spread is countercyclical. This mechanism generates a new type of financial accelerator, related to the market structure of the banking industry, which adds up to the one discussed in the literature on the credit channel. The loan markup depends positively on the level of borrowers' leverage and on the degree of the central bank's response to inflation in the Taylor rule.

The results identified in this paper are likely to have significant implications, both for the appropriate conduct of monetary policy and for financial stability considerations. For example, optimal monetary policy prescriptions may change once the strategic interaction between the central bank and large financial institutions is taken into account. Moreover, the effectiveness of various monetary and macroprudential policy settings may depend on the interaction of these policies with the behavior of non-atomistic banks. This analysis is left for future research.

Appendix 1. The Derivation of Equations (19) and (20)

From (14) and (15), we obtain

$$q_t^k - m^E q_{t+1}^k / R_t^b = \beta_E c_t^E / c_{t+1}^E \left[r_{t+1}^k + q_{t+1}^k (1 - m^E)(1 - \delta^k) \right]. \tag{43}$$

Using the definition of entrepreneurs' net worth in the text (18), the entrepreneurs' budget constraint can be rewritten as

$$c_t^E = nw_t^E - q_t^k k_t^E + b_t^E. \tag{44}$$

Now, we guess that entrepreneurs' consumption is a fraction $1 - \beta_E$ of net worth as follows:

$$c_t^E = (1 - \beta_E) nw_t^k. \tag{45}$$

Thus, plugging the guess into equation (43) yields

$$q_t^k k_t^E - b_t^E = \beta_E nw_t^E, \tag{46}$$

which corresponds to equation (20) in the text. Finally, in order to verify our initial guess and so equation (19), combine (46) and (44).

Appendix 2. The Bank's u Problem Solution

Impact of Bank Loan Rate on Aggregate Loan Rate

The loan rate set by a representative bank u is the same for all the types of loan supplied. We assume that each bank simultaneously sets the loan rate, $R_t^b(u)$, taking the other banks' loan rate as given. Thus, from the aggregate loan index,

$$R_t^b = \left[\int_0^1 R_t^b(j)^{1-\epsilon^b} \mathrm{d}j \right]^{\frac{1}{1-\epsilon^b}}, \tag{47}$$

we have that in a symmetric equilibrium, i.e., when $R_t^b(u) = R_t^b$,

$$\frac{\partial R_t^b}{\partial R_t^b(u)} = \frac{\partial}{\partial R_t^b(u)} \left[\int_{j \in u} R_t^b(j)^{1-\epsilon^b} \mathrm{d}j + \int_{j \notin u} R_t^b(j)^{1-\epsilon^b} \mathrm{d}j \right]^{\frac{1}{1-\epsilon^b}}$$
$$= \frac{1}{n} \left[\frac{R_t^b(u)}{R_t^b} \right]^{-\epsilon^b} = \frac{1}{n}. \quad (48)$$

Note that, because of symmetry, it is also true that

$$\frac{\partial R_t^b}{\partial R_t^b(u)} \frac{R_t^b(u)}{R_t^b} = \frac{\partial R_t^b}{\partial R_t^b(u)} = \frac{1}{n}. \quad (49)$$

Loan Demand and Policy Rate Elasticities to Aggregate Loan Rate Index

Define by

$$\Xi_{Z,t} \equiv \frac{\partial Z_t}{\partial R_t^b} \frac{R_t^b}{Z_t}$$

the elasticity of variable Z_t with respect to R_t^b. Banks' elasticities are computed *taking as given expectations* about variables in the next period.

When the borrowing constraint (8) is binding, we can use equations (21) and (23) and rewrite it as follows:

$$b_t^E = V_t^E LV_t^E nw_t^E.$$

As banks set the interest rate after having observed the entrepreneurs' net wealth (18), they also take the rental rate and price of capital as given. Thus, we can derive the following (perceived) relation

$$\Xi_{b,t} = \Xi_{V,t} + \Xi_{LV,t} = -1 + \Xi_{LV,t} \quad (50)$$

between the elasticity of loans demand and borrowers' leverage, which corresponds to $-\Sigma_{b,t}$ in the text (33).

Similarly, from the equilibrium condition for the labor market (19), the interest rate rule (1), and the production function (9), we obtain

$$\Xi_{y,t} + \Xi_{mc,t} + \Xi_{R^{ib},t} = (1+\phi)\Xi_{l^p,t}, \quad (51)$$

$$\Xi_{R^{ib},t} = \phi_\pi \Xi_{\pi,t}, \tag{52}$$

and

$$\Xi_{y,t} = (1-\alpha)\Xi_{l^p,t}. \tag{53}$$

Now, combining the budget constraint for households (3) and for entrepreneurs (7) yields the clearing condition in the final goods market:

$$y_t^E\left[1-\frac{\kappa_p}{2}(\pi_t-1)^2\right] = \frac{c_{t+1}^P}{\beta_P R_t^{ib}} + (1-\beta_E)nw_t^E \\ + LV_t^E nw_t^E - q_t k_{t-1}(1-\delta^k).$$

Differentiate with respect to R_t^b and evaluate at zero net inflation, $\pi_t = 1$, the above resource constraint; using $\frac{\partial Z_t}{\partial R_t^b} = \Xi_{Z,t}\frac{Z_t}{R_t^b}$, it reads

$$y_t \Xi_{y,t} = nw_t^E LV_t^E \Xi_{LV,t} - c_t^P \Xi_{R^{ib},t} \tag{54}$$

and the New Keynesian Phillips curve (25) leads to the following expression:

$$\kappa_p(mk^y - 1)\Xi_{\pi,t} = mk^y mc_t \Xi_{mc,t}. \tag{55}$$

Finally, taking logs of the entrepreneurs' leverage (23) and differentiating with respect to R_t^b yields

$$\Xi_{LV,t} = -\frac{V_t^E}{1-V_t^E} = 1 - \frac{LV_t^E}{\beta_E}, \tag{56}$$

which corresponds to $-\Sigma_{LV,t}$ in the text (34). Expression (35) is derived by solving the system of equations (51)–(55) for $\Xi_{Z,t}$, where $Z \in \{y,\ mc,\ R^{ib},\ l^p,\ \pi\}$.

Banks' First-Order Condition

Taking the derivative of (29) with respect to $R_t^b(u)$ and using (31) yields at the symmetric equilibrium, $R_t^b(j) = R_t^b$,

$$R_t^b - \frac{(n-1)\epsilon^b\left(R_t^b - R_t^{ib}\right)}{n} + \frac{\left(R_t^b - R_t^{ib}\right)\frac{\partial b_t^E}{\partial R_t^b}\frac{R_t^b}{b_t^E}}{n} - \frac{\frac{\partial R_t^{ib}}{\partial R_t^b}R_t^b}{n}. \tag{57}$$

Substituting for $\frac{\partial b_t^E}{\partial R_t^b} = -\Sigma_{b,t}\frac{b_t^E}{R_t^b}$ and $\frac{\partial R_t^{ib}}{\partial R_t^b} = -\Sigma_{R^{ib},t}\frac{R_t^{ib}}{R_t^b}$ yields expression (30) in the text.

Appendix 3. The Steady State

Without loss of generality, we normalize the technology parameter A^E so that $y^E = 1$ in steady state. From the Euler equation (4) and the firms' optimal condition in the capital goods sector (28), we have that $R^{ib} = 1/\beta_P$ and $q = 1$. Thus, in steady state, equations (21), (23), and (20) read

$$V^E = b^E/k^E, \tag{58}$$

$$LV = k^e/nw^E, \tag{59}$$

and

$$LV = \beta_E/(1 - V^E). \tag{60}$$

At zero inflation, the New Keynesian Phillips curve yields $mc = 1/mk^y$ and the resource constraint is given by

$$c^P + nw^E(LV^E - 1) - R^b b^E + \alpha/mk^y + nw^E(1 - \beta_E) = 1. \tag{61}$$

From equations (19), (8), and (18) we have that

$$(l^p)^{1+\phi} = \frac{1-\alpha}{c^P mk^y} \tag{62}$$

and

$$b^E R^b = k^E m^E (1 - \delta^k), \tag{63}$$

$$nw^E + R^b b^E - \alpha/mk^y - k^E(1 - \delta^k) = 0. \tag{64}$$

Equations (37), (38), and (39) are derived by solving the system of equations (58)–(64) for c^p, k^E, LV^E, b^E, nw^E, l^p, and V^E.

References

Adrian, T., and H. S. Shin. 2010. "Liquidity and Leverage." *Journal of Financial Intermediation* 19 (3): 418–37.

Albertazzi, U., and L. Gambacorta. 2009. "Bank Profitability and the Business Cycle." *Journal of Financial Stability* 5 (4): 393–409.

Aliaga-Díaz, R., and M. P. Olivero. 2010a. "Is There a Financial Accelerator in US Banking? Evidence from the Cyclicality of Banks' Price-Cost Margins." *Economics Letters* 108 (2): 167–71.

———. 2010b. "Macroeconomic Implications of 'Deep Habits' in Banking." *Journal of Money, Credit and Banking* 42 (8): 1495–1521.

Andrés, J., and O. Arce. 2012. "Banking Competition, Housing Prices and Macroeconomic Stability." *Economic Journal* 122 (565): 1346–72.

Andrés, J., Ó. Arce, and C. Thomas. 2013. "Banking Competition, Collateral Constraints and Optimal Monetary Policy." *Journal of Money, Credit and Banking* 45 (s2): 87–125.

Angelini, P., and N. Cetorelli. 2003. "The Effects of Regulatory Reform on Competition in the Banking Industry." *Journal of Money, Credit and Banking* 35 (5): 663–84.

Berger, A. N., A. Demirguc-Kunt, R. Levine, and J. G. Haubrich. 2004. "Bank Concentration and Competition: An Evolution in the Making." *Journal of Money, Credit and Banking* 36 (3): 433–51.

Bernanke, B., and M. Gertler. 1989. "Agency Costs, Net Worth, and Business Fluctuations." *American Economic Review* 79 (1): 14–31.

Bernanke, B. S., M. Gertler, and S. Gilchrist. 1999. "The Financial Accelerator in a Quantitative Business Cycle Framework." In *Handbook of Macroeconomics*, Vol. 1, Part C, ed. J. B. Taylor and M. Woodford, 1341–93 (chapter 21). Elsevier.

Bianchi, J. 2012. "Efficient Bailouts?" NBER Working Paper No. 18587.

Bikker, J. A., and K. Haaf. 2002. "Competition, Concentration and Their Relationship: An Empirical Analysis of the Banking Industry." *Journal of Banking and Finance* 26 (11): 2191–2214.

Calmfors, L. 2001. "Wages and Wage-Bargaining Institutions in the EMU: A Survey of the Issues." *Empirica* 28 (4): 325–51.

Carletti, E. 2008. "Competition and Regulation in Banking." In *Handbook of Financial Intermediation and Banking*, ed. A. Boot and A. Thakor, 449–82 (chapter 14). Elsevier, North Holland.

Cetorelli, N., and P. F. Peretto. 2012. "Credit Quantity and Credit Quality: Bank Competition and Capital Accumulation." *Journal of Economic Theory* 147 (3): 967–98.

Christiano, L., R. Motto, and M. Rostagno. 2010. "Financial Factors in Economic Fluctuations." ECB Working Paper No. 1192.

Chugh, S. K. 2009. "Firm Risk and Leverage-Based Business Cycles." Mimeo.

Claessens, S., and L. Laeven. 2004. "What Drives Bank Competition? Some International Evidence." *Journal of Money, Credit and Banking* 36 (3): 563–83.

Corbae, D., and P. D'Erasmo. 2013. "A Quantitative Model of Banking Industry Dynamics." Mimeo.

Corvoisier, S., and R. Gropp. 2002. "Bank Concentration and Retail Interest Rates." *Journal of Banking and Finance* 26 (11): 2155–89.

Cuciniello, V. 2011. "The Welfare Effect of Foreign Monetary Conservatism with Nonatomistic Wage Setters." *Journal of Money, Credit and Banking* 43 (8): 1719–34.

Cukierman, A. 2004. "Monetary Institutions, Monetary Union and Unionised Labour Markets: Some Recent Developments." In *Monetary Policy, Fiscal Policies and Labour Markets: Macroeconomic Policymaking in the EMU*, ed. R. Beetsma, C. Favero, A. Missale, V. A. Muscatelli, P. Natale, and P. Tirelli, 299–326 (chapter 11). Cambridge University Press.

Curdia, V., and M. Woodford. 2010. "Credit Spreads and Monetary Policy." *Journal of Money, Credit and Banking* 42 (s1): 3–35.

De Bandt, O., and E. P. Davis. 2000. "Competition, Contestability and Market Structure in European Banking Sectors on the Eve of EMU." *Journal of Banking and Finance* 24 (6): 1045–66.

Degryse, H., and S. Ongena. 2008. "Competition and Regulation in the Banking Sector: A Review of the Empirical Evidence on the Sources of Bank Rents." In *Handbook of Financial Intermediation and Banking*, ed. A. Boot and A. Thakor, 483–554 (chapter 15). Elsevier, North Holland.

Dell'Ariccia, G. 2001. "Asymmetric Information and the Structure of the Banking Industry." *European Economic Review* 45 (10): 1957–80.

Dell'Ariccia, G., E. Friedman, and R. Marquez. 1999. "Adverse Selection as a Barrier to Entry in the Banking Industry." *RAND Journal of Economics* 30 (Autumn): 515–34.

Demirguc-Kunt, A., L. Laeven, and R. Levine. 2004. "Regulations, Market Structure, Institutions, and the Cost of Financial Intermediation." *Journal of Money, Credit and Banking* 36 (3): 593–622.

Demsetz, H. 1973. "Industry Structure, Market Rivalry, and Public Policy." *Journal of Law and Economics* 16 (1): 1–9.

Dueker, M. J., and D. L. Thornton. 1997. "Do Bank Loan Rates Exhibit a Countercyclical Mark-up?" Technical Report.

Fama, E. F. 1985. "What's Different about Banks?" *Journal of Monetary Economics* 15 (1): 29–39.

Freixas, X., and J.-C. Rochet. 2008. *Microeconomics of Banking*, Vol. 1, 2nd Edition. The MIT Press.

Galí, J. 2008. *Monetary Policy, Inflation and the Business Cycle: An Introduction to the New Keynesian Framework*. Princeton, NJ: Princeton University Press.

Gerali, A, S. Neri, L. Sessa, and F. M. Signoretti. 2010. "Credit and Banking in a DSGE Model of the Euro Area." *Journal of Money, Credit and Banking* 42 (s1): 107–41.

Gertler, M., and P. Karadi. 2011. "A Model of Unconventional Monetary Policy." *Journal of Monetary Economics* 58 (1): 17–34.

Iacoviello, M. 2005. "House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle." *American Economic Review* 95 (3): 739–64.

Kashyap, A. K., and J. C. Stein. 2000. "What Do a Million Observations on Banks Say about the Transmission of Monetary Policy?" *American Economic Review* 90 (3): 407–28.

Kim, M., D. Kliger, and B. Vale. 2003. "Estimating Switching Costs: The Case of Banking." *Journal of Financial Intermediation* 12 (1): 25–56.

Kiyotaki, N., and J. Moore. 1997. "Credit Cycles." *Journal of Political Economy* 105 (2): 211–48.

Levy, A., and C. Hennessy. 2007. "Why Does Capital Structure Choice Vary with Macroeconomic Conditions?" *Journal of Monetary Economics* 54 (6): 1545–64.

Lippi, F. 2003. "Strategic Monetary Policy with Non-Atomistic Wage Setters." *Review of Economic Studies* 70 (4): 909–19.

Mandelman, F. S. 2011. "Business Cycles and the Role of Imperfect Competition in the Banking System." *International Finance* 14 (1): 103–33.

Maudos, J., and J. Fernandez de Guevara. 2004. "Factors Explaining the Interest Margin in the Banking Sectors of the European Union." *Journal of Banking and Finance* 28 (9): 2259–81.

Meh, C. A., and K. Moran. 2010. "The Role of Bank Capital in the Propagation of Shocks." *Journal of Economic Dynamics and Control* 34 (3): 555–76.

Olivero, M. P. 2010. "Market Power in Banking, Countercyclical Margins and the International Transmission of Business Cycles." *Journal of International Economics* 80 (2): 292–301.

Panzar, J. C, and J. N. Rosse. 1987. "Testing for 'Monopoly' Equilibrium." *Journal of Industrial Economics* 35 (4): 443–56.

Rotemberg, J. J. 1982. "Monopolistic Price Adjustment and Aggregate Output." *Review of Economic Studies* 49 (4): 517–31.

Salop, S. C. 1979. "Monopolistic Competition with Outside Goods." *Bell Journal of Economics* 10 (1): 141–56.

Soskice, D., and T. Iversen. 2000. "The Nonneutrality of Monetary Policy with Large Price or Wage Setters." *Quarterly Journal of Economics* 115 (1): 265–84.

Vives, X. 2001. "Competition in the Changing World of Banking." *Oxford Review of Economic Policy* 17 (4): 535–47.

von Thadden, E.-L. 1995. "Long-Term Contracts, Short-Term Investment and Monitoring." *Review of Economic Studies* 62 (4): 557–75.