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# Temi di Discussione
### (Working Papers)

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by Vincenzo Cuciniello and Federico M. Signoretti

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# LARGE BANKS, LOAN RATE MARKUP AND MONETARY POLICY

by Vincenzo Cuciniello* and Federico M. Signoretti*

## Abstract

This paper studies the implications of introducing large monopolistic banks, which can affect macroeconomic outcomes and thus the response of monetary policy to inflation, in a model with a collateral constraint linking the borrowers' credit capacity to the value of their durable assets. First, we find that strategic interaction generates a countercyclical loan spread, which amplifies the impact of monetary and technology shocks on the real economy. This type of financial accelerator adds up to the one due to financial frictions and is crucially related to the existence of non-atomistic banks. Second, the level of the spread and the degree of amplification are positively related to the level of entrepreneurs' leverage, reflecting the fact that higher leverage implies greater elasticity of the policy rate to changes in loan rates, which in turn increases banks' market power. Third, we find that amplification is stronger the more aggressive the central bank's response to inflation, as measured by the inflation coefficient in the Taylor rule.

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# 1 Introduction[1]

In the wake of the financial crisis of 2008 theoretical work aimed at incorporating financial intermediation in modern dynamic general equilibrium models (DSGE) has flourished (see Brunnermeier et al., 2012, for a review). This literature typically assumes that the market structure of the banking sector is either perfectly competitive (e.g. Christiano et al., 2010; Gertler and Karadi, 2011) or monopolistically competitive with atomistic banks (e.g. Gerali et al., 2010, henceforth GNSS; Andrés and Arce, 2012; Andrés et al., 2013), i.e. small banks whose individual decisions do not affect aggregate outcomes. Yet, a distinctive feature of the banking sector in many advanced economies is the presence of very large players: as an example, in 2011 the three largest banks in the European Union and the US accounted for 60 and 30 per cent, respectively, of total banking sector assets (Bijlsma and Zwart, 2013).

In this paper we aim at bridging this gap, by providing the first formal analysis of non-atomistic banks in a stochastic dynamic general equilibrium New Keynesian environment. In particular, we are interested in studying a setup in which few large players understand that their behavior has an effect on aggregate variables and interacts with other players' behavior. In this setup strategic complementarities arise, altering the dynamics of competition in the banking industry with respect to a framework with perfect competition or monopolistic competition with atomistic banks.

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 (e.g. Lawler, 2000; Cukierman and Lippi, 2001; Lippi, 2003; Soskice and Iversen, 2000; Guzzo and Velasco, 1999).[2] In particular, we start from a baseline New

[2]Of course, the existence of large and complex financial institutions not only affects competition in the banking sector. The literature assessing the influence of big banks

Keynesian model with borrowing constraints and a concentrated banking sector, and relax the assumption that there is an infinite amount of atomistic banks in the economy. 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. The intermediaries also realize that this choice interacts with the choices of the other banks and with the response of the central bank. As a consequence, the equilibrium (aggregate) level of the loan spread is affected by the number of banks, which proxy for the level of concentration in the economy and determine the degree of strategic interaction (for $n \to \infty$ the strategic effects disappear). In addition, due to the strategic interaction, the loan spread is a function of the elasticity of the *aggregate loan demand* and of the *policy rate* to changes in (a given) bank's loan rate.[3]

In this context, we find important implications for the level and cyclical properties of the bank loan markup. *First*, the presence of strategic interaction generates a countercyclical bank price-cost margin (loan spread). This mechanism 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. This accelerator *adds up* to the standard financial accelerator discussed in the literature on the credit channel (Bernanke and Gertler, 1989; Bernanke et al., 1999; Kiyotaki and Moore, 1997), which is also at work in our model due to the presence of borrowing-constrained agents. The existence of an amplification mechanism connected with banks' market power is consistent with empirical evidence (as discussed in Section 2 below). *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

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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 new macro literature emerged after the crisis which have made significant progress in terms of incorporating loan spreads and studying loan rate setting behavior by banks (e.g. Curdia and Woodford, 2010; Andrés and Arce, 2012; GNSS).

[3]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. Corbae and D'Erasmo, 2013; Cetorelli and Peretto, 2012). In this paper, instead, not only banks internalize the effect of their decisions on the aggregate loan rate, but also on the polity rate, thereby strategically interacting with the central bank.

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, as net worth tends to fall (increase) more than assets after shocks that negatively (positively) affect output. *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.

As an intuition for the results above, 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 by reducing its marginal costs to a larger extent.

The mechanism described above is consistent with the large banks' 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.[4] In these analyses, con-

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[4]For example, Deutsche Bank's *Focus Europe* newsletter regularly discusses about future ECB's decisions, Barclays's *Global Economics Weekly* about Bank of England's, JP Morgan's *Global Data Watch* and Bank of America-Merril Lynch's *Global Economic Weekly* about Federal Reserve's. Similarly, one can easily find large bank CEOs' or other executives' interviews or website state-

ditions in the credit market are often mentioned as an important driver for the prospected central bank decisions. Also, the effect of monetary policy decisions on bank funding costs are sometimes explicitly considered.[5] Indeed, conditions on the credit markets *are* one of the crucial things that most central banks look at when deciding monetary policy stance.[6] 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.[7] 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. Cukierman and Lippi, 2001) and, more broadly, are fully consistent with the rational expectations framework.

Our paper is related to a number of other recent works that have studied the role of banking in business cycle fluctuations. Christiano et al. (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 model of horizontal product differentiation, with N 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

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ments about future policy decisions. See for example: for the US, 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 Eurozone, BNP Paribas (http://video.cnbc.com/gallery/?video=3000252516); for Sweden, Nordea (http://cbonds.it/news/item/608543); 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).

[5] 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 Eurozone countries. The estimated impact is a reduction in cost ranging between 75 basis points in Germany and 195 in Italy.

[6] Credit market conditions are regularly mentioned in the ECB's *Introductory Statement* or the FOMC's Press Release, following the central banks' meetings.

[7] For example, Bank of America, Barclays and UBS' loan market shares are well above 10%.

capture new borrowers. Aliaga-Díaz and Olivero (2010b) and GNSS 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. Differently to all these papers, we model a strategic interaction among the large banks and with 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 fail-

ure of perfect competition.[8] 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 (von Thadden, 1995; Dell'Ariccia et al., 1999; Dell'Ariccia, 2001; Kim et al., 2003). 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 et al., 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. De Bandt and Davis, 2000; Bikker and Haaf, 2002; Claessens and Laeven, 2004).[9]

Assuming that bank's 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 byproduct 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 com-

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

[9]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.

petition is less intense in more concentrated markets because collusion is easier (Degryse and Ongena, 2008).[10] Despite after the 1990s this paradigm evolved past this simple framework, recent empirical evidence overall supports a positive relation between concentration and market power.[11] For example, Bikker and Haaf (2002) estimate the Panzar and Rosse (1987) H-statistic for 23 industrialized countries over a period of roughly 10 years and relate these measure to various measures of concentration (various $k$-bank concentration ratios, the Herfindahl 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 50 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 (Dueker and Thornton, 1997; Angelini and Cetorelli, 2003; Mandelman, 2011; Corbae and D'Erasmo, 2013). 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 et al. (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'

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[10]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 bank realize that they can affect aggregate outcomes, thus exploiting the strategic interaction with the central bank.

[11]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).

(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. Secondly, using aggregate data from the IMF 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 reports data for US 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.[12] 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 US, 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.

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[12]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.

# 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-good producers, which is combined with labor to produce homogenous intermediate goods, consume, and borrow from banks. Due to the existence of financial frictions (modelled along Iacoviello, 2005), lending is collateralized with physical capital. The banking sector is constituted by a finite number $n$ of *large* banks, who operate in a regime of imperfect competition in the loan market and internalize the effects of their loan rate decisions on the aggregate economy.[13] In addition to entrepreneurs, there are two 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 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:

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

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[13]The way in which the banking sector is modeled is based on GNSS. The main departure from their framework is that we allow for fully flexible rates and banks are assumed to be non-atomistic.

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.[14] The parameters $\phi$ and $\beta_P$ denote the inverse of the Frisch labor supply elasticity and the households' discount factor.

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:

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

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

In the equations above $c_t^E(i)$ is entrepreneurs' consumption, $b_t^E(i)$ is the

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[14]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 the GNSS 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.

amount of borrowing from banks, $R_t^b$ is the (gross) aggregate interest rate on loans, $w_t$ is real wage, 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, $\delta^k$ is 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 $\beta_E$ 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 $\varsigma^{A^E}$.

Entrepreneurs' demand for loans is derived as in GNSS. 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 $\epsilon^b$ (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 from 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 loan 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:

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

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

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

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

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

where $\lambda_t^E$ 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.[15] 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

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[15]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.

(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 et al. (2013), we can define entrepreneurs' net worth as follows:[16]

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

Using (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 A 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-

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[16]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 $q_{t+1}^k \left(1-\delta^k\right) k_t^E$ to the capital sector; (iii) pay back $R_t^b b_t^E$ to banks. Thus, in equation (18) $r_t^k k_{t-1}^E + q_t^k \left(1-\delta^k\right) k_{t-1}^E$ 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.

capital ratio and the entrepreneurs' leverage ($LV_t^E$):

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

## 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 which includes a markup over the purchasing cost.[17] The introduction of retailers is useful for introducing nominal rigidities. In particular, in our model we assume that retailers face a quadratic adjustment cost parameterized by $\kappa_p$ whenever they want to change their price (Rotemberg, 1982). In particular, retailers' maximize the following profit function

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

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:

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

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

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[17]For example, Bernanke et al. (1999) and GNSS use the same modeling device.

$P_t/P_t^W$.

In addition, we assume that fixed capital creation is carried out by *capital-good 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 $c_t^E$ the current consumption. The first-order condition is:

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

## 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 modelled along GNSS, with a Dixit-Stiglitz type of competition.[18]

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[18]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

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 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 $u \in \{1, \ldots, n\}, n \geq 2$) sets the same interest rate $R_t^b(u)$ on all loans provided to entrepreneurs $j \in u$ so as to maximize profits:

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

subject to the loan demand (11), the budget constraints (3), (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:

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

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

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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.

[19]In particular, the condition is:

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

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.

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 B) 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

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[20]For a complete derivation of this expression and of its components see Appendix B.

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:

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

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

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bank's inflation coefficient $\phi_\pi$, which determines the intensity of monetary policy response for 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 margin. In the real world, bank profit and loss statements obviously includes many other items, such as trading and other non-interest income, operating costs, 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 $\beta_P$ is set at 0.996, which implies a steady-state policy rate of roughly 2% (annualized). The entrepreneurs' discount factor $\beta_E$ has to be smaller than $\beta_P$ and is set at 0.97, as in Iacoviello (2005).[25] The inverse of the Frisch elasticity $\phi$ is set at 1 (Galí, 2008). The share of

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[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 15).

capital in the production function ($\alpha$) and the depreciation rate of physical capital ($\delta^k$) 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 GNSS. The parameter governing the investment adjustment cost ($\kappa^i$) 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 GNSS, where it roughly moves one-to-one with GDP. The degree of price stickiness $\kappa_p$ is set at 30, corresponding to a Calvo-probability of not being able to adjust prices of roughly 66%, which implies that adjustment occurs, on average, every 3 quarters. The elasticity of substitution across goods $\epsilon^y$ is set at 6, implying a markup in the goods market of 20%. In the Taylor rule, the baseline calibration for the strength of monetary policy response to inflation $\phi_\pi$ 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. The elasticity of substitution across loan varieties $\epsilon^b$ (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 C for the derivation):

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

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

Table 1: Baseline calibration

|  | Value | Description |
|---|---|---|
| $\beta_P$ | 0.996 | household discount factor |
| $\beta_E$ | 0.97 | entrepreneurial discount factor |
| $\phi$ | 1 | inverse Frisch elasticity of labor supply |
| $\alpha$ | 0.30 | product elasticity with respect to physical capital |
| $m^E$ | 0.80 | entrepreneurs LTV ratio |
| $\epsilon^b$ | 161 | elasticity of substitution of loans |
| $\epsilon^y$ | 6 | elasticity of substitution of goods |
| $\kappa_p$ | 30 | price stickiness |
| $\kappa_i$ | 0.4 | investment adjustment cost |
| $\delta^k$ | 0.01 | depreciation rate of physical capital |
| $\varsigma^{A^E}$ | 0.01 | TFP standard deviation innovation |
| $\varsigma^{R^{ib}}$ | 0.0025 | monetary policy standard deviation innovation |
| $\phi_\pi$ | 1.5 | Strength of monetary policy response to inflation |

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

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

where the markup in equation (36) is given by:

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

and

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

$$\Sigma_b = LV^E/\beta_E. \qquad (42)$$

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 3 (blue line), 5 (red), 10 (black) and 30 (green).
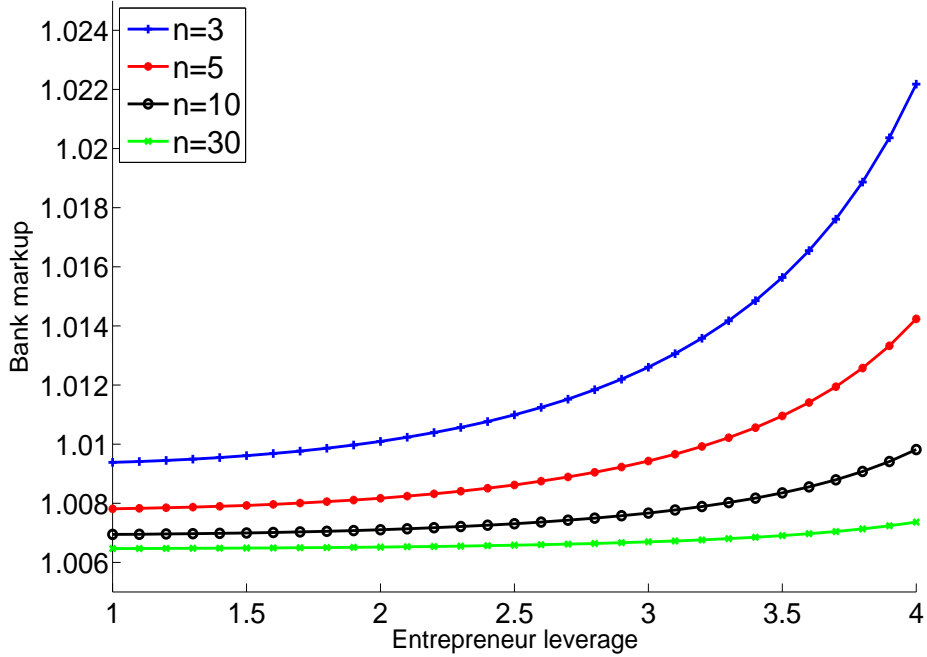


Figure 1: Relation between bank markup and entrepreneurs' leverage, for different values of the number of banks operating in the loan market.

A number of considerations are in order. First, the markup is positively related with 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 $\Sigma_b$ 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 $\phi_\pi$, $n$, and the bank's markup $\mathcal{M}^b$ in a tridimensional plot (with the the remaining parameters still 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 far 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 $\phi_\pi$ 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 $\phi_\pi$ stabilizes inflation to a larger extent, but it induces an increase in the degree of monopolistic power of banks in the long run.
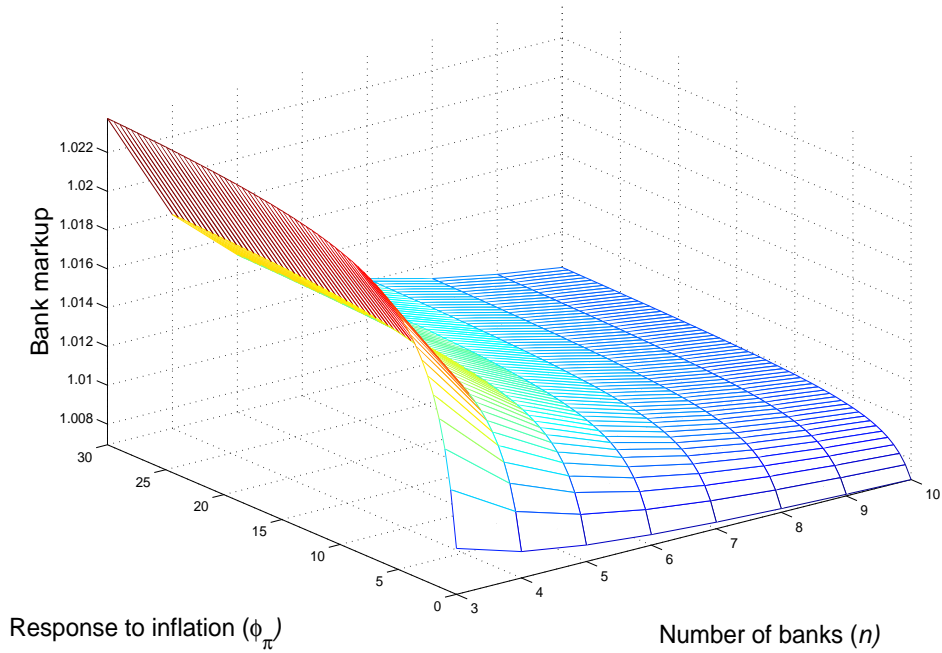


Figure 2: Relation between bank markup, the degree of monetary policy aggressiveness towards inflation and the number of banks operating in the loan market.

# 5 The financial acceleration markup and the propagation of shocks

We now turn to studying the dynamic responses of the model to a monetary and a technology shocks, showing the impact of different calibrations for $n$ and $\phi_\pi$. We again refer to Table 1 for the calibration of the other parameters. Since $n$ and $\phi_\pi$ affect the steady state of the model, in the simulations we assume the existence of a subsidy $\Upsilon$ (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 $\phi_\pi$ at 1.5. The blue lines correspond to the case of atomistic banks, while the red dotted lines correspond to the case of large banks with a loan market share of around 30 percent, i.e. $n = 3$.

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 fi-

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[27]Note that, given the existence of this subsidy, differently to footnote 15, the condition $\beta_P > \beta_E$ is sufficient to guarantee that the borrowing constraint is always binding, similarly to Iacoviello (2005).

*nancial 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 et al., 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.
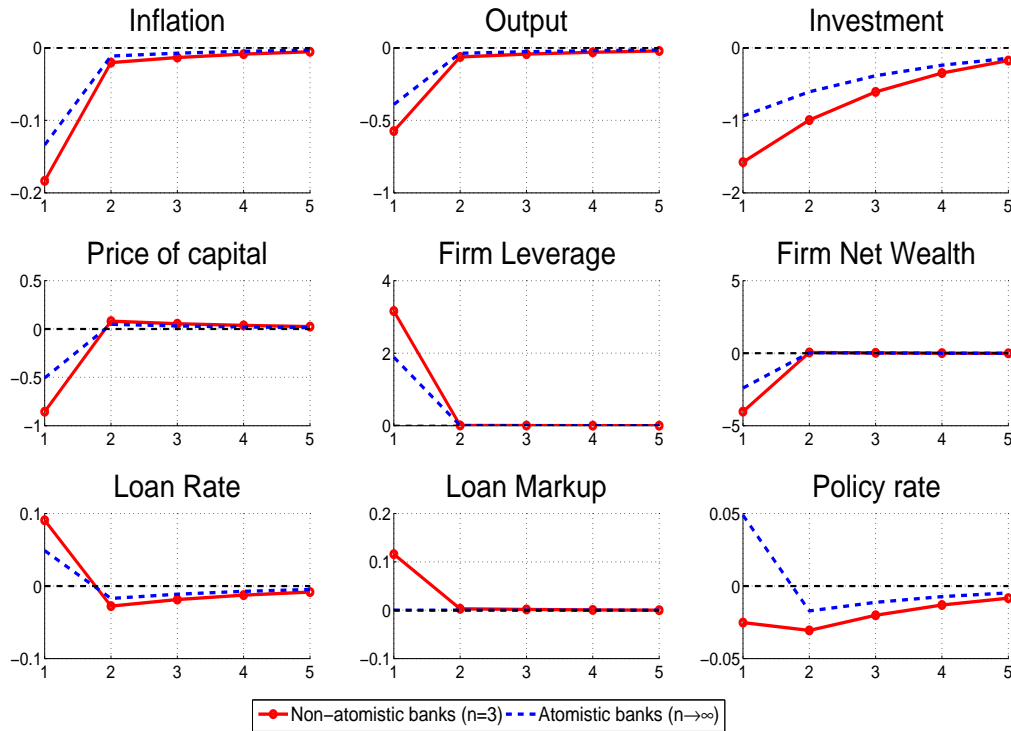


Figure 3: Impulse response to a one standard deviation contractionary monetary shock. Comparing the models with atomistic and large banks. Percent deviation from steady state.

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 that case of atomistic banks. Again, the explanation is that the presence of large banks implies a countercyclical movement in bank's 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.
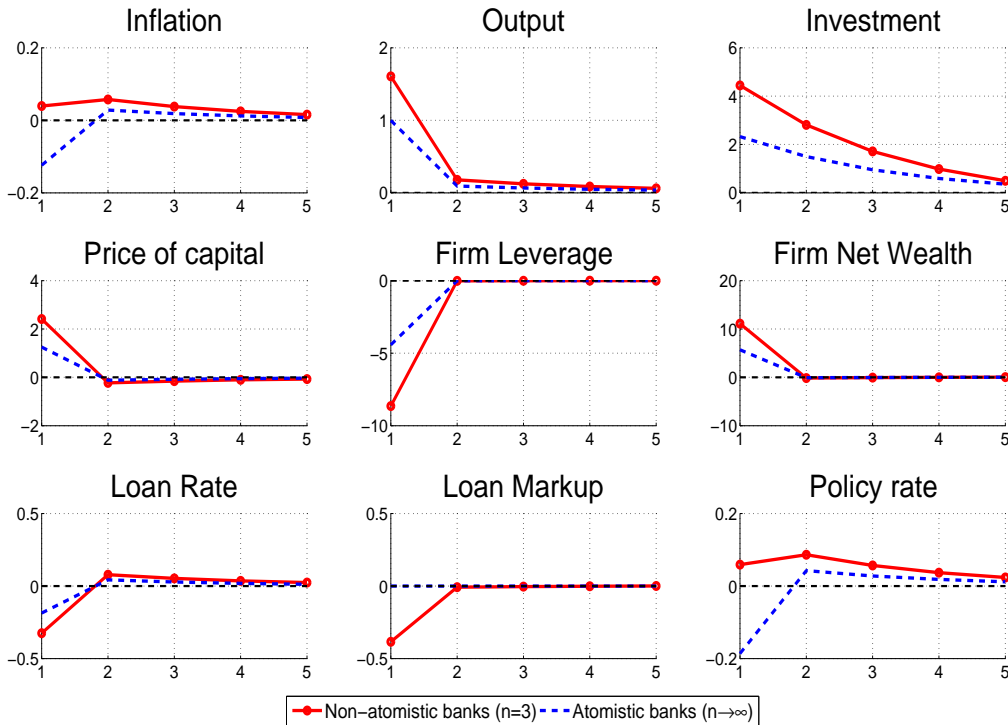


Figure 4: Impulse response to a one standard deviation expansionary technology shock. Comparing the models with atomistic and large banks. Percent deviation from steady state.

In the previous two exercises, we kept the value of the central bank's inflation coefficient $\phi_\pi$ fixed at 1.5. However, as we noted 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
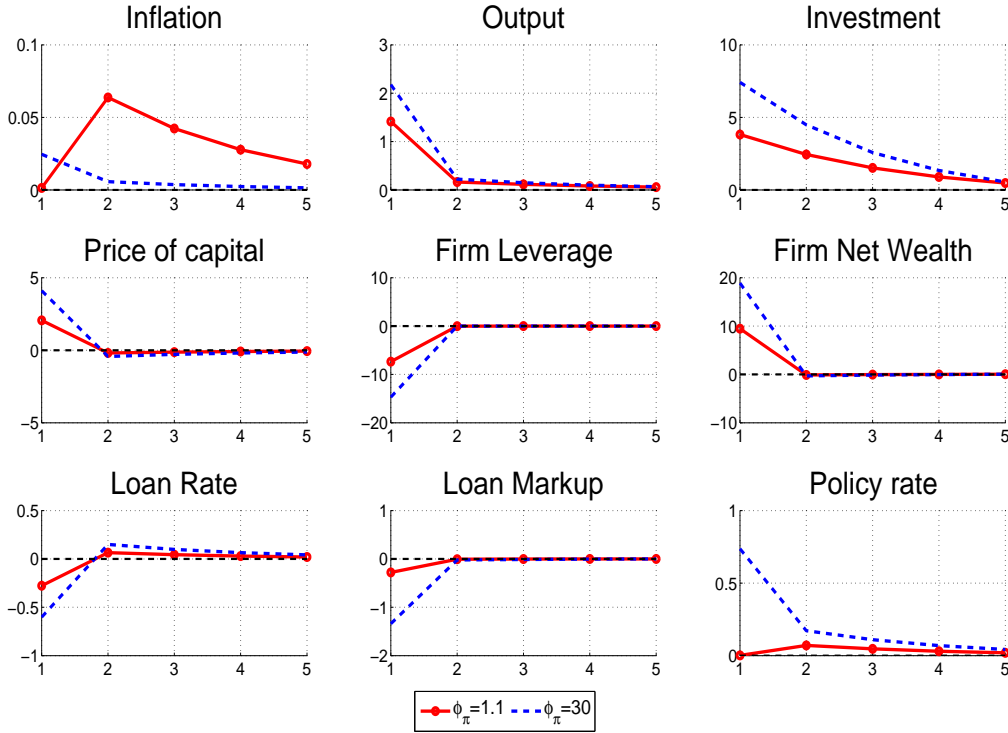
Figure 5: Effect of different inflation coefficients with a positive technological shock and $n = 3$. Percent deviation from steady state.

$(n = 3)$, 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.

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

# 6 Conclusions

This paper extends a New-Keynesian model with banks and financial frictions to allow for the presence of large banks, i.e. intermediaries that understand and internalize the aggregate effects of their individual decisions. This framework gives rise to a strategic interaction between the banks and the central bank, which alters the dynamics of competition in the banking industry.

In this framework, the presence of strategic interaction has an effect on the steady-state and the cyclical behavior of the bank price-cost margin, which in turn affects the rest of the macroeconomic variables. In particular, while in a benchmark model with atomistic banks the loan markup is constant and depends only on the (exogenous) elasticity of substitution among loan varieties, in the model with large banks it is endogenous and 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 endogenous movements in the loan spread are countercyclical, generating a new type of financial accelerator which adds up to the one discussed in the literature on the credit channel and is consistent with empirical evidence.

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 macro-prudential policy settings may depend on the interaction of these policies with the behavior of non-atomistic banks. This analysis is left for future research.

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# Appendices

# A    The derivation of equations (19) and (20)

From (14) and (15), we obtain

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

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

$$c_t^E = n w_t^E - q_t^k k_t^E + b_t^E. \qquad \text{(A.2)}$$

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

$$c_t^E = (1 - \beta_E) n w_t^k. \tag{A.3}$$

Thus, plugging the guess into equation (A.1) yields

$$q_t^k k_t^E - b_t^E = \beta_E n w_t^E \tag{A.4}$$

which corresponds to equation (20) in the text. Finally, in order to verify our initial guess and so equation (19), combine (A.4) and (A.2).

# B The bank's $u$ problem solution

## An 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,

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

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

$$
\begin{aligned}
\frac{\partial R_t^b}{\partial R_t^b(u)} &= \frac{\partial}{\partial R_t^b(u)} \left[ \int_{j \in u} R_t^b(j)^{1-\epsilon^b} \mathrm{d}j + \int_{j \notin u} R_t^b(j)^{1-\epsilon^b} \mathrm{d}j \right]^{\frac{1}{1-\epsilon^b}} \\
&= \frac{1}{n} \left[ \frac{R_t^b(u)}{R_t^b} \right]^{-\epsilon^b} = \frac{1}{n}.
\end{aligned} \tag{B.2}
$$

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

$$\frac{\partial R_t^b}{\partial R_t^b(u)} \frac{R_t^b(u)}{R_t^b} = \frac{\partial R_t^b}{\partial R_t^b(u)} = \frac{1}{n}. \tag{B.3}$$

## Loans 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 $R_t^b$. Bank's 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

$$\Xi_{b,t} = \Xi_{V,t} + \Xi_{LV,t} = -1 + \Xi_{LV,t} \tag{B.4}$$

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

$$\Xi_{y,t} + \Xi_{mc,t} + \Xi_{R^{ib},t} = (1+\phi)\Xi_{l^p,t}, \tag{B.5}$$

$$\Xi_{R^{ib},t} = \phi_\pi \Xi_{\pi,t}, \tag{B.6}$$

and

$$\Xi_{y,t} = (1-\alpha)\Xi_{l^p,t}. \tag{B.7}$$

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

$$y_t\Xi_{y,t} = nw_t^E LV_t^E \Xi_{LV,t} - c_t^P \Xi_{R^{ib},t} \tag{B.8}$$

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

$$\kappa_p(mk^y - 1)\Xi_{\pi,t} = mk^y mc_t\Xi_{mc,t}. \tag{B.9}$$

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

$$\Xi_{LV,t} = -\frac{V_t^E}{1 - V_t^E} = 1 - \frac{LV_t^E}{\beta_E}, \tag{B.10}$$

which corresponds to $-\Sigma_{LV,t}$ in the text (34). Expression (35) is derived by solving the system of equations (B.5)-(B.9) for $\Xi_{Z,t}$ where $Z \in \{y,\ mc,\ R^{ib},\ l^p,\ \pi\}$.

## Banks' first-order condition

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

$$R_t^b - \frac{(n-1)\epsilon^b\left(R_t^b - R_t^{ib}\right)}{n} + \frac{\left(R_t^b - R_t^{ib}\right)\frac{\partial b_t^E}{\partial R_t^b}\frac{R_t^b}{b_t^E}}{n} - \frac{\frac{\partial R_t^{ib}}{\partial R_t^b}R_t^b}{n} \tag{B.11}$$

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.

# C   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 good sector (28), we have that $R^{ib} = 1/\beta_P$ and $q = 1$. Thus, in steady state equations (21), (23), and (20) read:

$$V^E = b^E/k^E, \tag{C.1}$$

$$LV = k^e/nw^E, \tag{C.2}$$

and

$$LV = \beta_E/(1 - V^E). \tag{C.3}$$

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

$$c^P + nw^E(LV^E - 1) - R^b b^E + \alpha/mk^y + nw^E(1 - \beta_E) = 1. \tag{C.4}$$

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

$$(l^p)^{1+\phi} = \frac{1 - \alpha}{c^P mk^y} \tag{C.5}$$

and

$$b^E R^b = k^E m^E(1 - \delta^k), \tag{C.6}$$

$$nw^E + R^b b^E - \alpha/mk^y - k^E(1 - \delta^k) = 0. \tag{C.7}$$

Equations (37), (38), and (39) are derived by solving the system of equations (C.1)-(C.7) for $c^p$, $k^E, LV^E$, $b^E$, $nw^E$, $l^p$ and $V^E$.

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