Imperfect Banking Competition and Macroeconomic Volatility: A DSGE Framework

Jiaqi Li*

Bank of Canada

July 5, 2020

[Link to the Latest Version]

Abstract

This paper studies the impact of imperfect banking competition on aggregate fluctuations by developing a DSGE framework that features a Cournot banking sector. I propose a new propagation mechanism of imperfect banking competition that operates via the dynamics of the expected marginal product of capital. After a contractionary monetary policy shock, a higher real interest rate implies a higher expected return on capital, which tends to make firms' capital demand less sensitive to the loan rate. Since capital is financed by bank loans, a more inelastic capital demand maps into a more inelastic loan demand. Banks with market power take advantage of the lower loan demand elasticity by charging a higher loan rate, thus reducing firms' demand for capital and hence output by more relative to perfect banking competition.

*This paper is based on one chapter of my Ph.D. thesis. I am deeply indebted to my Ph.D. supervisor, Petra Geraats, for her invaluable advice and continuous support. I am very grateful to Thorsten Beck and Tiago Cavalcanti for the constructive feedback on the previous version of this paper. I thank Anil Ari, Adrien Auclert, Charles Brendon, Narayan Bulusu, River Chen, Jonathan Chiu, Giancarlo Corsetti, Sihua Ding, Chryssi Giannitsarou, Xing Guo, Lu Han, Simon Lloyd, Gonzalo Morales, Maarten van Oordt, Donald Robertson, Jean-Charles Rochet, Yaz Terajima, Jasmine Xiao, Erhao Xie, Xu Zhang and Yu Zhu for helpful conversations. I thank participants in the Ph.D. Macroeconomic Workshop at University of Cambridge and Brown Bag Seminar at the Bank of Canada for the useful comments.

1 Introduction

The banking sector tends to be dominated by a few large players. In most EU and OECD countries, the largest five banks account for more than 60% of the market share.[1] While there has been an increasing focus on the role of financial frictions in amplifying aggregate fluctuations since the global financial crisis, imperfect banking competition is often overlooked as most of the existing literature tends to focus on agency problems between borrowers and lenders. Does imperfect banking competition matter for aggregate fluctuations? If so, via which channel?

Intuitively, the answer to these questions is straightforward. Under imperfect banking competition, the loan rate tends to be higher than the deposit rate as banks charge a loan rate markup above its marginal cost (i.e., the deposit rate). If this loan markup (the ratio of loan rate over deposit rate) changes over the business cycle, the loan rate no longer moves one-to-one with the deposit rate. A countercyclical loan markup will amplify the aggregate fluctuations as a higher loan rate would reduce investment and output by more relative to perfect banking competition and likewise, a procyclical loan markup attenutates aggregate fluctuations.

There are several seminal papers that study the impact of imperfect banking competition on aggregate fluctuations via an endogenously changing loan markup. They either rely on a binding borrowing constraint (Cuciniello and Signoretti, 2015; Andrés and Arce, 2012) or limit pricing strategy of banks to deter entry (Mandelman, 2011, 2010). These assumptions only apply to specific circumstances and cannot explain how imperfect banking competition propagates macroeconomic shocks if borrowers are not financially constrained or if the competitive pressure from entry is minimal so that banks do not practice limit pricing to deter entry.

By developing a DSGE framework that features a Cournot banking sector, this paper shows that even under a general model setup, imperfect banking competition can still have important amplification effects of macroeconomic shocks. Instead of relying on specific assumptions, the amplification effect in this paper is generated through the general equilibrium dynamics in the expected marginal product of capital. This is based on the observation that firms' interest rate elasticity of capital demand – a key component driving the loan markup – monotonically decreases in the expected marginal product of capital. Therefore, any shock that raises the expected marginal product of capital also makes the capital demand more inelastic. Since firms finance the purchase of capital using bank loans and their own net worth,

[1] Author's calculation based on ECB and Bankscope data in 2007 and 2014; for empirical evidence on imperfect banking competition and banks' market power, see Bikker and Haaf (2002), Ehrmann et al. (2001), De Bandt and Davis (2000), Oxenstierna (1999) and Berg and Kim (1998), etc.

changes in capital demand elasticity map into the loan demand elasticity. In addition, when firms' leverage ratio is higher, implying a greater reliance on bank loans, the loan demand tends to be more inelastic. Banks with market power respond to the changing loan demand elasticity by adjusting their loan markup.

This paper finds that the loan markup dynamics are shock-specific, unlike the existing literature that finds a countercyclical loan markup after both monetary policy and productivity shocks (Cuciniello and Signoretti, 2015; Andrés and Arce, 2012; Mandelman, 2011, 2010). After a contractionary monetary policy shock, firms reduce their capital demand due to a rise in the real interest rate. This leads to a drop in output while consumption does not drop as much since households want to smooth their consumption. As consumption gradually rises towards its steady state, the real interest rate is high to induce households to save for future consumption. Under perfect banking competition, this dynamics of the real interest rate (equivalent to the real deposit or loan rate) mirror the dynamics of the expected return on capital, as banks simply channel households' savings into financing firms' capital input for production. A higher expected return on capital implies that firms' capital and thus loan demand is more inelastic. Under imperfect banking competition, banks with market power will take advantage of the more inelastic loan demand by charging a higher loan markup. This countercyclical loan markup reduces capital and output by more relative to perfect banking competition and slows down the output recovery due to its persistent effect via capital accumulation.

By contrast, after a negative productivity shock, the loan markup is initially procyclical and later on countercyclical. This is because there are two opposite forces that drive the expected marginal product of capital. On the one hand, a persistently low productivity tends to lower the expected marginal product of capital. On the other hand, there is an upward pressure on the real interest rate to induce households to save for future consumption so that consumption can rise towards its steady state. A higher real interest rate tends to raise the expected marginal product of capital. As a result, the expected marginal product of capital falls during the early periods but then rises during later periods, making the capital and loan demand more elastic initially but more inelastic later on. If the negative productivity shock is fully transitory such that firms' productivity rises back to its steady state in the period after the shock, the downward pressure on the expected marginal product of capital due to the persistently low productivity disappears and the results are similar to a contractionary monetary policy shock.

This paper is closely related to the recent efforts in incorporating imperfect banking competition into DSGE models. In the existing literature, imperfect banking competition is often modelled via monopolistic competition within the Dixit and Stiglitz (1977) framework (Hafstead and Smith, 2012; Dib, 2010; Gerali et al., 2010; Hülsewig, Mayer and Wollmershäuser, 2009). This monopolistic competition model implies a constant loan markup.[2] More recent studies find a countercyclical loan markup by using Salop's (1979) model of monopolistic competition (Andrés and Arce, 2012), introducing large banks into the Dixit and Stiglitz (1977) framework (Cuciniello and Signoretti, 2015), or limit pricing strategy by banks to deter entry (Mandelman, 2011, 2010). This paper uses a Cournot banking sector to characterise oligopolistic competition among banks. The implication that the loan markup depends negatively on the number of banks and the loan demand elasticity is similar to the former two approaches.

Different model setups and assumptions on banks' strategic considerations can lead to different factors that explain the loan markup dynamics. In Andrés and Arce (2012) and Cuciniello and Signoretti (2015), firms are always financially constrained, so the effective market loan demand is given by the binding borrowing constraint that is tied to the collateral value as well as the loan rate. Due to the binding constraint, a higher loan rate directly reduces firms' borrowing capacity and hence the loan demand. In this setup, a higher leverage ratio implies more borrowing can be pledged against one unit of the collateral asset. When the leverage ratio is higher, the loan demand is more elastic as one percentage change in the loan rate leads to a greater reduction in loan demand. By contrast, when firms are financially unconstrained as in this paper, a higher leverage ratio implies greater reliance on bank loans and a more inelastic loan demand. They find that after an adverse shock, the leverage ratio goes up, which tends to lower the loan margin (difference between the loan rate and deposit rate) in their model setups. To generate the countercyclical loan margin, they rely on some other channels.[3] Mandelman (2011, 2010) assumes an implicit collusion agreement between incumbent banks and strategic limit pricing to deter entry. During good times, a larger loan market size leads to higher competitive pressure from new entrants, so banks would want to lower the loan markup to deter entry.

The main contribution of this paper is to study imperfect banking competition in a more

[2] In all these papers, changes in the loan margin over the business cycle are generated by introducing exogenous shocks to the elasticity of substitution between different loan or deposit products (e.g., Gerali et al., 2010) or bank's marginal cost of producing loans (e.g., Hafstead and Smith, 2012), or modelling interest rate stickiness *à la* Calvo (1983) or Rotemberg (1982) (e.g., Dib, 2010; Gerali et al., 2010; Hülsewig, Mayer and Wollmershäuser, 2009).

[3] Andrés and Arce (2012) find that the downward pressure on the loan margin through a higher leverage ratio is dominated by the rise in banks' marginal cost (deposit rate) that tends to push up the loan margin. Cuciniello and Signoretti (2015) rely on the strategic interaction between banks with market power and an inflation-targeting central bank (i.e., banks internalize the endogenous response of the policy rate to the loan rate, as well as the loan demand elasticity) to generate the countercyclical loan markup. However, this mechanism does not apply to countries that have a fixed exchange rate regime or are part of a large monetary union (such as the eurozone).

general setup that does not rely on firms being financially constrained or intense competitive pressure from entry that induces banks to practice limit pricing strategy. In this paper, the loan demand comes from firms' optimal capital demand. I assume that firms finance the purchase of new capital using a non-state-contingent loan contract from banks and their own net worth. Under imperfect banking competition, the loan rate is higher than the deposit rate, so net worth becomes a cheaper source of financing than bank loans and firms would invest all their net worth in capital and borrow the rest from banks. Since net worth is unaffected by the current period loan rate, the loan demand elasticity is driven by the capital demand elasticity. I find that capital and loan demand are more inelastic when the expected marginal product of capital is higher. Since different shocks affect the dynamics of the expected marginal product of capital differently, this paper also finds that the cyclicality of loan markup is shock-specific, which differs from the existing literature. While the loan markup is countercyclical after a monetary policy shock, it can be procyclical after a productivity shock.

This paper is also related to a large literature that incorporates an agency problem between borrowers and lenders into a DSGE model to study the financial accelerator effect. As borrowers' balance sheet conditions worsen during bad times, agency problems become more severe, and the resulting increased difficulty in obtaining external finance tends to amplify any shocks that adversely affect balance sheet conditions (Bernanke, Gertler and Gilchrist, 1996).[4] While this paper focuses on imperfect banking competition in the absence of agency problems, I obtain similar qualitative results via the role of firms' net worth.[5] This paper finds that an adverse shock that reduces firms' net worth can increase firms' reliance on bank loans, which tends to make the loan demand more inelastic, leading to a countercyclical loan markup that amplifies the effect of the adverse shock.

The remainder of the paper is structured as follows. Section 2 introduces the DSGE framework with a perfectly competitive banking sector, which is used as a benchmark in the dynamic analysis. Cournot banking competition is then introduced to replace the perfectly competition banking sector, while the rest of the model setup remains the same. Section

[4]The agency problem is often modelled by costly debt enforcement (Gertler, Kiyotaki and Queralto, 2012; Gertler and Karadi, 2011; Gertler and Kiyotaki, 2010; Iacoviello, 2005; Kiyotaki and Moore, 1997). As borrowers cannot be forced to repay unsecured debt (Beck, Colciago and Pfajfar, 2014), creditors would not lend an amount that exceeds the value of collateralized assets and hence borrowers face a collateral constraint. Alternatively, the agency problem can be modelled by the costly state verification of Townsend (1979) that leads to an endogenous external finance premium, which then raises the cost of borrowing and amplifies business cycle fluctuations (Agénor and Montiel, 2015; Gilchrist, Ortiz and Zakrajsek, 2009; Bernanke, Gertler and Gilchrist, 1999; Carlstrom and Fuerst, 1997).

[5]In this paper, the loan contract is non-state-contingent, so an adverse shock can cause firms to go bankrupt ex post. This paper models firms' net worth accumulation to abstract away from firms' default probability, as net worth can absorb the potential losses.

3 explains the calibration of model parameters. Section 4 shows the impulse responses of some key variables after a contractionary monetary shock, a persistent and a fully transitory negative productivity shock. Section 5 discusses robustness checks, and Section 6 concludes.

2 The Model

The model aims to show the effect of imperfect banking competition relative to perfect banking competition on aggregate fluctuations in a New Keynesian DSGE framework. Section 2.1 shows the model set-up for perfect banking competition and Section 2.2 replaces the perfectly competitive banking sector with a Cournot banking sector.

2.1 Perfect Banking Competition Benchmark

There are six types of agents: households, firms, capital producers, retailers, banks, and a central bank. Households consume, supply labor to the firms, and decide how much to save via one-period non-state-contingent nominal bank deposit contracts or one-period risk-free nominal bonds. Perfectly competitive firms are born with some net worth in the initial period. In each period, they purchase new capital from capital producers for production in the following period, where capital is financed by net worth and one-period non-state-contingent nominal bank loan contracts. The wholesale good produced by firms cannot be consumed directly and is sold to monopolistically competitive retailers who then differentiate the wholesale good costlessly into different varieties. Each retailer uses the wholesale good as the only input to produce a different variety. The final consumption good is a composite CES (constant elasticity of substitution) bundle of all the varieties. Perfectly competitive capital producers buy the undepreciated capital from firms and consumption goods from retailers to produce new capital, which is sold back to the firms.

Banks offer two types of one-period contracts: deposit contracts and loan contracts. The contracts are denominated in nominal terms, which means they are not inflation-indexed and the borrowing or saving decisions are made on the basis of a preset contractual nominal loan or deposit rate. Assuming nominal bank deposits and one-period riskless nominal bonds are perfect substitutes to households under full deposit insurance,[6] the gross nominal deposit rate must equal the gross nominal interest rate R_t earned on the riskless nominal bond invested in period t. Since banks are perfectly competitive, each of them takes the nominal loan rate as given and maximizes its profit with respect to the loan (or deposit) quantity. Assuming

[6] This paper abstracts away from the deposit insurance premium in the banking sector's problem.

costless financial intermediation and no expected default on loans,[7] the gross nominal loan rate $R_{b,t}$ equals the gross nominal deposit rate R_t, which is controlled by the central bank.

2.1.1 Households

There is a continuum of identical infinitely-lived households of unit mass. The representative household maximizes the following expected utility:

$$E_t \sum_{s=0}^{\infty} \beta^s [ln(c_{t+s}) + \phi ln(1 - l_{t+s})] \tag{1}$$

which depends on consumption c and labor supply l, with E_t being the expectation operator conditional on information in period t, and $\beta \in (0, 1)$ the subjective discount factor of the household. The total time endowment is normalised to 1, so $(1 - l_t)$ denotes the amount of period-t leisure time, and $\phi > 0$ is the relative utility weight on leisure.

In each period t, the household consumes c_t, saves d_t in real (final consumption) terms, and supplies labor hours l_t. Assume there is zero net supply of risk-free nominal bonds, so in equilibrium, households hold only nominal bank deposits. The nominal deposits d_{t-1} saved in period $t - 1$ earn a gross nominal interest rate R_{t-1} at the beginning of period t. Let p_t denote the unit price of the final consumption good, then the gross inflation rate is $\pi_t \equiv \frac{p_t}{p_{t-1}}$. Assume households own the firms, retailers, and banks. Given the gross real interest earnings on deposits $\frac{R_{t-1}d_{t-1}}{\pi_t}$ at the beginning of period t, real labor income $w_t l_t$ and real dividends Π_t^F, Π_t^R, Π_t^{CP} and Π_t^B from firms, retailers, capital producers and the banking sector respectively, households decide how much to consume and save in period t. Hence, the representative household faces the following budget constraint:

$$c_t + d_t = \frac{R_{t-1}d_{t-1}}{\pi_t} + w_t l_t + \Pi_t^F + \Pi_t^R + \Pi_t^{CP} + \Pi_t^B \tag{2}$$

Let λ_t denote the Lagrange multiplier associated with the budget constraint or equivalently, the marginal utility of consumption. The first order conditions with respect to consumption c_t (3), labor supply l_t (4), and bank deposits d_t (5) are as follows:

$$\lambda_t = \frac{1}{c_t} \tag{3}$$

[7] Under reasonable calibration, the steady state net worth of the firm is large enough that even after a persistent and large negative productivity shock (five times its standard deviation), the net worth is far from being negative. Hence, this paper neglects the possibility of default on loans.

$$\frac{\phi}{1-l_t} = \lambda_t w_t \tag{4}$$

$$\lambda_t = \beta E_t \left[\lambda_{t+1} \frac{R_t}{\pi_{t+1}} \right] \tag{5}$$

Equation (5) is the standard intertemporal Euler equation, which can also be written as:

$$1 = E_t \left[\Lambda_{t,t+1} \frac{R_t}{\pi_{t+1}} \right] \tag{6}$$

where $\Lambda_{t,t+1} \equiv \beta \frac{\lambda_{t+1}}{\lambda_t} = \beta \frac{u'(c_{t+1})}{u'(c_t)}$ is the stochastic discount factor in period t for real payoffs in period $t+1$, with $u(c) = ln(c)$.

2.1.2 Firms

A continuum of perfectly competitive firms of unit mass purchase new capital k_{t-1} from capital producers at a real price q_{t-1} in period $t-1$ for production in period t. Capital k_{t-1} and labor l_t hired from households are used to produce the wholesale good $y_{w,t}$ via a constant-returns-to-scale Cobb-Douglas production technology:

$$y_{w,t} = z_t k_{t-1}^{\alpha_k} l_t^{\alpha_l} \tag{7}$$

where $\alpha_k \in (0,1)$ and $\alpha_l \in (0,1)$ are the output elasticities of physical capital and labor respectively. The wholesale good produced in period t is sold to retailers at a nominal price $p_{w,t}$, who then produce the final consumption good sold at a nominal price p_t. Productivity z_t follows an AR(1) process in logs:

$$lnz_t = \psi lnz_{t-1} + e_{z,t} \tag{8}$$

with $\psi \in (0,1)$ indicating the persistence of the process, and $e_{z,t}$ normally distributed with mean zero and variance σ_z^2.

Assume firms start with net worth n_0 in the initial period which is insufficient to finance the capital k_0. Hence, firms borrow b_0 from banks to purchase the new capital k_0 at a real capital price q_0 from capital producers for production in the following period. Let $R_{b,t-1}$ denote the gross nominal loan rate in period $t-1$, then at the beginning of period t, the gross real loan interest payment is $\frac{R_{b,t-1}b_{t-1}}{\pi_t}$. In each period t, the net worth of a firm j equals the sum of the realized output in terms of the final consumption units $\frac{y_{w,t}(j)}{x_t}$ and the revenue from selling the undepreciated capital stock to capital producers $q_t(1-\delta)k_{t-1}(j)$, net of the real wage cost $w_t l_t(j)$ and the gross real loan interest payment $\frac{R_{b,t-1}b_{t-1}(j)}{\pi_t}$:

$$n_t(j) = \frac{y_{w,t}(j)}{x_t} - w_t l_t(j) + q_t(1-\delta)k_{t-1}(j) - \frac{R_{b,t-1}b_{t-1}(j)}{\pi_t} \tag{9}$$

where $x_t \equiv \frac{p_t}{p_{w,t}}$ denotes the markup of the price of the final consumption good over the price of the wholesale good. After the net worth $n_t(j)$ is realized and before choosing the capital $k_t(j)$ for production in period $t+1$, assume there is an exogenous death shock such that the firm exits with a probability $\varphi \in (0,1)$, in which case the firm transfers its net worth to households as dividend payments. This assumption ensures that firms cannot quickly accumulate enough net worth to self-finance the purchase of capital. A surviving firm j chooses the amount of capital $k_t(j)$ to purchase at a real price q_t. Given its net worth $n_t(j)$, the firm needs to borrow $b_t(j)$ from banks:

$$b_t(j) = q_t k_t(j) - n_t(j) \tag{10}$$

Since bank loans are assumed to be non-state-contingent, firms' net worth is introduced as a buffer to absorb any ex post losses. If firms had no net worth, a negative productivity shock that lowers the realized output could cause firms to go bankrupt. To determine firms' loan demand and thus examine the interest rate elasticity of the loan demand, which is a key component for the loan markup under imperfect banking competition, I assume that capital is financed by the firm's net worth and bank loans. This assumption is innocuous when the lending rate and the saving rate are identical, in which case it does not matter whether firms use net worth or debt to finance the capital. By contrast, when the lending rate is higher than the saving rate due to imperfect banking competition, net worth becomes a cheaper source of financing compared to bank loans. In this case, firms prefer to invest all their net worth into capital and have incentives to delay consumption until exit to accumulate net worth over time.

Let $\Lambda_{t,t+s} \equiv \beta^s \frac{u'(c_{t+s})}{u'(c_t)}$ denote the stochastic discount factor, since households own the firms. Each surviving firm j in period t chooses its capital $k_t(j)$ and labor $l_t(j)$ to maximize the expected discounted terminal net worth:

$$E_t \sum_{\tau=0}^{\infty} \varphi(1-\varphi)^{\tau} \Lambda_{t,t+1+\tau} n_{t+1+\tau}(j) \tag{11}$$

Since firms are financially unconstrained, their net worth does not affect their optimal choices of capital and labor. Hence, I neglect the subscript j in the first order conditions with respect to capital (12) and labor (13):

$$E_t\Lambda_{t,t+1}\left[\frac{z_{t+1}\alpha_k k_t^{\alpha_k-1}l_{t+1}^{\alpha_l}}{x_{t+1}}+q_{t+1}(1-\delta)-\frac{R_{b,t}q_t}{\pi_{t+1}}\right]=0 \tag{12}$$

$$\frac{z_t\alpha_l k_{t-1}^{\alpha_k}l_t^{\alpha_l-1}}{x_t}=w_t \tag{13}$$

Rearranging (12), the aggregate demand for capital $k_t=\int k_t(j)dj$ for a given level of labor hours is:

$$k_t=\left(\frac{E_t\Lambda_{t,t+1}\left[\frac{R_{b,t}q_t}{\pi_{t+1}}-q_{t+1}(1-\delta)\right]}{E_t\Lambda_{t,t+1}\left[\frac{z_{t+1}\alpha_k l_{t+1}^{\alpha_l}}{x_{t+1}}\right]}\right)^{-\frac{1}{1-\alpha_k}} \tag{14}$$

which decreases in the gross loan rate $R_{b,t}$ set by the banking sector. Firms choose the optimal capital after knowing their net worth $n_t(j)$ in period t and borrow the difference between the two $b_t(j)$. As a result, the market loan demand $b_t=\int b_t(j)dj$ is the difference between the value of optimal capital and the aggregate net worth $n_t=\int n_t(j)dj$:

$$b_t=q_tk_t-n_t \tag{15}$$

Assume in each period t, the fraction φ of exiting firms are replaced by new firms, each with an initial net worth of $\frac{\omega}{\varphi}q_tk_{t-1}$ transferred from households. The aggregate net worth is the sum of the net worth of the surviving firms $(1-\varphi)\int n_t(j)dj$ and the net worth of the new entering firms ωq_tk_{t-1}:

$$n_t=(1-\varphi)\left[\frac{y_{w,t}}{x_t}-w_tl_t+q_t(1-\delta)k_{t-1}-\frac{R_{b,t-1}b_{t-1}}{\pi_t}\right]+\omega q_tk_{t-1} \tag{16}$$

where $\omega\in(0,1)$ helps determine the steady state firm leverage ratio $\frac{k}{n}$. The net dividend received by households Π_t^F is the total net worth of the exiting firms net of the transfer to the new entering firms. When the production function exhibits constant returns to scale, the firm's steady state net worth is $n=(1-\varphi)\frac{R_bn}{\pi}+\omega qk$ using the first order conditions (12) and (13), so φ and ω need to be positive to ensure a positive steady state net worth that can absorb ex post losses.

2.1.3 Capital Producers

Perfectly competitive capital producers purchase undepreciated capital $(1-\delta)k_{t-1}$ at the real price q_t from firms and i_t units of final consumption goods from retailers to produce new capital k_t at the end of period t:

$$k_t = i_t + (1-\delta)k_{t-1} \tag{17}$$

where i_t is also gross investment. The new capital produced will be sold back to the entrepreneur at the real price q_t, which will be used to produce the wholesale good in period $t+1$. Following Christiano, Eichenbaum and Evans (2005), assume capital producers face investment adjustment costs that depend on the gross growth rate of investment $\frac{i_t}{i_{t-1}}$. Assume old capital can be converted one-to-one into new capital and a quadratic unit investment adjustment cost $f\left(\frac{i_t}{i_{t-1}}\right) = \frac{\chi}{2}\left(\frac{i_t}{i_{t-1}}-1\right)^2$ is only incurred in the production of new capital when using the final consumption good as the input, where $f(1) = f'(1) = 0$, $f''(1) > 0$ and $\chi > 0$. This specification of the adjustment cost implies that fewer units of new capital would be produced from one unit of investment whenever $\frac{i_t}{i_{t-1}}$ deviates from its steady state value of one and the parameter χ reflects the magnitude of the cost.

Hence, the representative capital producer chooses the gross investment level i_t to maximize the sum of the expected discounted future profits made from the sales revenue of new capital $q_t k_t$ net of the input cost $[q_t(1-\delta)k_{t-1} + i_t]$ and the investment adjustment cost $f\left(\frac{i_t}{i_{t-1}}\right) i_t$:

$$E_t \sum_{s=0}^{\infty} \Lambda_{t,t+s} \left[q_t k_t - q_t(1-\delta)k_{t-1} - i_t - \frac{\chi}{2}\left(\frac{i_t}{i_{t-1}}-1\right)^2 i_t \right] \tag{18}$$

where $\Lambda_{t,t+s} \equiv \beta^s \frac{u'(c_{t+s})}{u'(c_t)}$ is the stochastic discount factor, since households own the capital producers. Using (17), the objective function (18) can be simplified to:

$$E_t \sum_{s=0}^{\infty} \Lambda_{t,t+s} \left[(q_t - 1)i_t - \frac{\chi}{2}\left(\frac{i_t}{i_{t-1}}-1\right)^2 i_t \right] \tag{19}$$

Taking the first order condition with respect to investment i_t gives the following expression for the real price of capital:

$$q_t = 1 + \frac{\chi}{2}\left(\frac{i_t}{i_{t-1}}-1\right)^2 + \chi \frac{i_t}{i_{t-1}}\left(\frac{i_t}{i_{t-1}}-1\right) - \chi E_t \left[\Lambda_{t,t+1} \left(\frac{i_{t+1}}{i_t}\right)^2 \left(\frac{i_{t+1}}{i_t}-1\right) \right] \tag{20}$$

In the steady state, the real price of capital q is one, since $i_{t+1} = i_t = i_{t-1}$. Any real profits Π_t^{CP} (which only arise outside the steady state) are rebated to the households, where $\Pi_t^{CP} = (q_t - 1)i_t - \frac{\chi}{2}\left(\frac{i_t}{i_{t-1}}-1\right)^2 i_t$. To focus on the role of imperfect banking competition, the investment adjustment cost parameter χ is set to zero in the baseline analysis, so that the capital price q_t remains one throughout.

2.1.4 Retailers

To analyse monetary policy shocks, it is essential to introduce nominal price rigidity, which makes monetary policy have real effects. I introduce nominal rigidity by assuming the retailers are monopolistically competitive and set prices *à la* Calvo (1983).

A continuum of retailers of unit mass, indexed by j, buy the wholesale good at a nominal price $p_{w,t}$ from entrepreneurs and use it as the only input to produce differentiated retail goods costlessly. Assume that one unit of the wholesale good can produce one unit of the differentiated product, so the marginal cost of production is the real price of the wholesale good $\frac{p_{w,t}}{p_t}$. Each retailer j produces a different variety $y_t(j)$ and charges a nominal price $p_t(j)$ for the differentiated product. The output of the final consumption good y_t is a constant elasticity of substitution (CES) composite of all the different varieties produced by the retailers, using the Dixit and Stiglitz (1977) framework:

$$y_t = \left[\int_0^1 y_t(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}} \tag{21}$$

where $\epsilon > 1$ is the elasticity of intratemporal substitution between different varieties. Given the aggregate output index y_t, it can be calculated from the cost minimization problem of the buyers of the final consumption good that each retailer j faces a downward-sloping demand curve:

$$y_t(j) = \left[\frac{p_t(j)}{p_t} \right]^{-\epsilon} y_t \tag{22}$$

It can be shown that the aggregate consumption-based price index is:

$$p_t = \left[\int_0^1 p_t(j)^{1-\epsilon} dj \right]^{\frac{1}{1-\epsilon}} \tag{23}$$

which is defined as the minimum expenditure to obtain one unit of consumption y_t in the cost minimization problem for the final output users.

Each retailer j sets its own price $p_t(j)$ taking the aggregate price p_t and the demand curve (22) as given. Under Calvo pricing, each retailer j is only allowed to change its price $p_t(j)$ in period t with probability $(1-\theta)$. The probability of price adjustment is independent of the time since the last adjustment, so in each period, a fraction $(1-\theta)$ of retailers reset their prices, whereas a fraction θ of retailers keep their prices fixed. Hence, $\theta \in (0, 1)$ reflects the degree of price stickiness. Let $p_t^*(j)$ denote the optimal reset price in period t, then the corresponding demand facing retailer j who adjusted its price in period t, but cannot adjust its price in period $t+s$, is:

$$y^*_{t+s}(j) = \left[\frac{p^*_t(j)}{p_{t+s}}\right]^{-\epsilon} y_{t+s} \tag{24}$$

Retailer j chooses $p^*_t(j)$ to maximize the expected discounted value of real profits while its price is kept fixed at $p^*_t(j)$:

$$\sum_{s=0}^{\infty} \theta^s E_t \left[\Lambda_{t,t+s}\left\{\frac{p^*_t(j)}{p_{t+s}} y^*_{t+s}(j) - \frac{1}{x_{t+s}} y^*_{t+s}(j)\right\}\right] \tag{25}$$

subject to the demand function (24), where $\Lambda_{t,t+s} \equiv \beta^s \frac{u'(c_{t+s})}{u'(c_t)}$ is the stochastic discount factor, since households own the retailers, θ^s is the probability that $p^*_t(j)$ would remain fixed for s periods, and $\frac{1}{x_{t+s}} = \frac{p_{w,t+s}}{p_{t+s}}$ is the price of the wholesale good in terms of the consumption units or the real marginal cost of production in period $t+s$. Taking the first order condition to solve for $p^*_t(j)$ gives the following optimal pricing equation:

$$p^*_t(j) = \frac{\epsilon}{\epsilon - 1} \frac{\sum_{s=0}^{\infty} (\beta\theta)^s E_t \left[u'(c_{t+s}) x^{-1}_{t+s} p^{\epsilon}_{t+s} y_{t+s}\right]}{\sum_{s=0}^{\infty} (\beta\theta)^s E_t \left[u'(c_{t+s}) p^{\epsilon-1}_{t+s} y_{t+s}\right]} \tag{26}$$

The derivation is shown in Appendix B.1. In a symmetric equilibrium, all the retailers that adjust their prices in period t will set the same optimal price, such that $p^*_t(j) = p^*_t$. It is proved in Appendix B.2 that the aggregate price level evolves as follows:

$$p^{1-\epsilon}_t = \theta p^{1-\epsilon}_{t-1} + (1-\theta)(p^*_t)^{1-\epsilon} \tag{27}$$

which is independent of the heterogeneity of the retailers due to the convenience of the Calvo assumption. With randomly chosen price-adjusting retailers and the large number of retailers, there is no need to keep track of each retailer's price evolution.

Since there is a one-to-one conversion rate from the wholesale good to the differentiated retail good, in equilibrium the supply of wholesale good output $y_{w,t}$ is equal to the demand $y_t(j)$ over the entire unit interval of retailers j. Using retailer $j's$ individual demand function (22), the wholesale good output can be expressed as:

$$y_{w,t} = \int_0^1 y_t(j)dj = y_t \int_0^1 \left[\frac{p_t(j)}{p_t}\right]^{-\epsilon} dj \tag{28}$$

As seen from the above equation, the final consumption good output y_t differs from the wholesale good output $y_{w,t}$ by a factor of the price dispersion $\int_0^1 \left[\frac{p_t(j)}{p_t}\right]^{-\epsilon} dj$. In a zero-inflation steady state, the price dispersion is one and the final output y_t would equal the wholesale good output $y_{w,t}$. Use (28) and let $f_{3,t} \equiv \int_0^1 \left[\frac{p_t(j)}{p_t}\right]^{-\epsilon} dj$ denote the price dispersion, then the real profit Π_t^R made by the retailers is:

$$\Pi_t^R = y_t - \frac{y_{w,t}}{x_t} = \left(\frac{1}{f_{3,t}} - \frac{1}{x_t}\right) y_{w,t} \tag{29}$$

which will be rebated back to the households. The recursive formulation of the price dispersion used for numerical computation and the derivation for Π_t^R are shown in Appendix B.3.

2.1.5 Banking Sector

Assume there is a continuum of banks of mass one, indexed by j, which are perfectly competitive with no price-setting power. The gross nominal interest rate R_t is controlled by the central bank and is thus taken as given. Following Andrés and Arce (2012) and Cuciniello and Signoretti (2015), assume all bank profits $\Pi_t^B(j)$ are distributed as dividends to households each period, so $\Pi_t^B = \sum_j \Pi_t^B(j)$. Since there is no possibility of loan default in this paper,[8] there is no need to model the bank capital. Assume there is zero bank capital, so bank loans (assets) equal the deposits (liabilities):

$$b_t(j) = d_t(j) \tag{30}$$

In each period t, the total outflow of funds, consisting of the dividend payment to households $\Pi_t^B(j)$, loans granted to firms $b_t(j)$, and the gross real deposit interest payments to households $\frac{R_{t-1}d_{t-1}(j)}{\pi_t}$, equals the total inflow of funds from the deposits saved by households $d_t(j)$ and the gross real loan interest payments received from firms $\frac{R_{b,t-1}b_{t-1}(j)}{\pi_t}$. Assuming costless financial intermediation, each bank j faces the following budget constraint:

$$\Pi_t^B(j) + b_t(j) + \frac{R_{t-1}d_{t-1}(j)}{\pi_t} = d_t(j) + \frac{R_{b,t-1}b_{t-1}(j)}{\pi_t} \tag{31}$$

Each bank j chooses the units of loans $b_t(j)$ and the units of deposits $d_t(j)$ to maximize the sum of the expected discounted value of real profits:

$$E_t \sum_{s=0}^{\infty} \Lambda_{t,t+s} \Pi_t^B(j) \tag{32}$$

[8] Recall that this paper neglects the possibility of loan default since it is extremely unlikely under reasonable calibration, as discussed in Section 2.1.2.

subject to the balance sheet identity (30) and the budget constraint in real terms (31). Substituting (30) into (31) simplifies the bank's real profit $\Pi_t^B(j)$ to:

$$\Pi_t^B(j) = \frac{1}{\pi_t}(R_{b,t-1} - R_{t-1})b_{t-1}(j) \tag{33}$$

Taking the first order condition of (32) with respect to $b_t(j)$ gives:

$$E_t\left[\Lambda_{t,t+1}\frac{1}{\pi_{t+1}}(R_{b,t} - R_t)\right] = 0 \tag{34}$$

Since $\Lambda_{t,t+1} > 0$ and $\pi_{t+1} \equiv \frac{p_{t+1}}{p_t} > 0$, the nominal loan interest margin $(R_{b,t} - R_t)$ is zero. With perfect banking competition and no expected default on loans, the market-determined gross nominal loan rate $R_{b,t}$ equals R_t.

2.1.6 Central Bank

Suppose monetary policy is implemented by a Taylor rule with interest rate smoothing, which responds to both the deviation of the gross inflation rate from the inflation target π and the deviation of output from its steady state y. The central bank controls the gross nominal interest rate R_t on risk-free bonds and bank deposits, following the Taylor rule specification below:

$$R_t = \rho_r R_{t-1} + (1-\rho_r)\left[R + \kappa_\pi(\pi_t - \pi) + \kappa_y(y_t - y)\right] + e_{r,t} \tag{35}$$

where variables without time subscript represent steady state values, and $e_{r,t}$ is a monetary policy shock which is a white noise process with zero mean and variance σ_r^2. The coefficient $\rho_r \in [0,1]$ is the interest rate smoothing parameter, and κ_π and κ_y are non-negative feedback parameters that reflect the sensitivity of the interest rate to output and inflation deviations. Due to interest rate smoothing, this policy rule implies a partial adjustment of R_t. The policy rate R_t is a weighted average of the lagged nominal interest rate R_{t-1} and the current target rate, which depends positively on the deviation of inflation from its target and the deviation of output from its steady state value.

To focus on the model mechanism, I assume the Taylor rule takes the simplest possible form by setting ρ_r and κ_y to zero in the baseline analysis.[9] Let $R_{r,t}$ denote the gross real interest rate, then the relation between the nominal and real interest rates is given by the Fisher equation:

$$R_{r,t} = E_t\left[\frac{R_t}{\pi_{t+1}}\right] \tag{36}$$

[9]When $\kappa_y = 0$, the Taylor principle implies that $\kappa_\pi > 1$ will ensure the nominal interest rate R_t is raised sufficiently in response to an increase in the gross inflation rate π_t so that the real interest rate rises.

2.2 Imperfect Banking Competition

This section replaces the perfectly competitive banking sector with an imperfectly competitive banking sector in the same model set-up described in Section 2.1. As the banking sector tends to be dominated by a few large players, a Cournot banking sector is used to characterise oligopolistic competition and capture the market power possessed by banks.[10] In a Cournot equilibrium, banks' quantity-setting decisions affect the market loan rate. Assume now there are N banks in the economy, indexed by j, which operate under Cournot competition. Each bank takes into account the effect of its choice $b_t(j)$ on firms' capital and loan demand through the equilibrium loan rate, but it ignores general equilibrium effects and takes other prices and aggregate quantities as given. Each bank j sets the quantity of loans $b_t(j)$, taking the loan quantities chosen by the other banks $m \neq j$ as given, to maximize the sum of the present discounted value of future profits:

$$E_t \sum_{s=0}^{\infty} \Lambda_{t,t+s} \Pi_t^B(j) \tag{37}$$

where

$$\Pi_t^B(j) = \frac{1}{\pi_t} \left[R_{b,t-1} \left(b_{t-1}(j) + \sum_{m \neq j} b_{t-1}(m) \right) - R_{t-1} \right] b_{t-1}(j) \tag{38}$$

The real profit $\Pi_t^B(j)$ is positive due to imperfect competition and will be rebated back to the households. A key difference from Section 2.1.5 is that $R_{b,t}(.)$ now represents the inverse loan demand function, which depends on b_t and thereby $b_t(j)$. This is crucial for introducing imperfect banking competition. The dependence of $R_{b,t}$ on $b_t(j)$ means that each bank j has some control over the equilibrium gross loan interest rate by altering its own quantity of loans given the other banks' loan quantities and this is taken into consideration by bank j under Cournot competition when choosing $b_t(j)$. Solving the profit maximization problem with respect to $b_t(j)$ gives the following first order condition:

$$E_t \left[\Lambda_{t,t+1} \frac{1}{\pi_{t+1}} \left\{ \frac{\partial R_{b,t}}{\partial b_t(j)} b_t(j) + R_{b,t} - R_t \right\} \right] = 0 \tag{39}$$

In a Cournot equilibrium, the total optimal loan quantity is $b_t = b_t(j) + \sum_{m \neq j} b_t(m)$ and each bank produces a share of the total quantity. Assuming banks are identical, then $b_t(j) = \frac{b_t}{N}$ in equilibrium. Since $\frac{\partial R_{b,t}}{\partial b_t(j)} = \frac{\partial R_{b,t}}{\partial b_t} \frac{\partial b_t}{\partial b_t(j)} = \frac{\partial R_{b,t}}{\partial b_t}$, in Cournot equilibrium, the first order

[10] Bertrand price competition between two identical banks will lead to a perfectly competitive outcome as they undercut each other. This is unrealistic since banks do have market power in reality. For empirical evidence, see Oxenstierna (1999), Berg and Kim (1998), etc.

condition (39) can be rewritten as:

$$E_t\left[\Lambda_{t,t+1}\frac{1}{\pi_{t+1}}\left\{\frac{\partial R_{b,t}}{\partial b_t}\frac{b_t}{N}+R_{b,t}-R_t\right\}\right]=0 \tag{40}$$

where the market loan demand b_t is given by $b_t = q_t k_t - n_t$ (15). Since the firm's net worth n_t is independent of the current period loan rate $R_{b,t}$, b_t is affected by the loan rate through firms' demand for capital. When bank j chooses $b_t(j)$, which affects the equilibrium gross loan rate $R_{b,t}$ under Cournot competition, it needs to consider how firms would respond by changing their demand for physical capital $\frac{\partial k_t}{\partial R_{b,t}}$.

It is shown in Appendix A that firms' demand for capital decreases in the loan rate $\frac{\partial k_t}{\partial R_{b,t}} < 0$ and the interest rate elasticity of capital demand $PEK_t \equiv -\frac{\partial k_t}{\partial R_{b,t}}\frac{R_{b,t}}{k_t}$ monotonically decreases in the expected marginal product of capital:

$$PEK_t = \frac{1}{1-\alpha_k}\left(1+\frac{E_t\Lambda_{t,t+1}[q_{t+1}(1-\delta)]}{E_t\Lambda_{t,t+1}\left[MPK_{t+1}\right]}\right) \tag{41}$$

where $MPK_{t+1} \equiv \frac{z_{t+1}\alpha_k k_t^{\alpha_k-1} l_{t+1}^{\alpha_l}}{x_{t+1}}$ is the marginal product of capital in real (final consumption) terms. In the baseline analysis, I assume old capital can be costlessly converted into new capital by perfectly competitive capital producers so that the real price of capital q_t is one throughout. Since capital is financed by loans and net worth n_t, the market loan demand elasticity PED_t is driven by the capital demand elasticity PEK_t as well as firms' leverage ratio that captures their reliance on bank loans. Using (15), the market loan demand is more inelastic (i.e., lower PED_t) when capital demand is more inelastic and firms' leverage ratio $\frac{b_t}{q_t k_t}$ is higher:

$$PED_t \equiv -\frac{\partial b_t}{\partial R_{b,t}}\frac{R_{b,t}}{b_t} = -\frac{\partial k_t}{\partial R_{b,t}}\frac{R_{b,t}}{k_t}\frac{k_t}{b_t} = PEK_t\frac{q_t k_t}{b_t} \tag{42}$$

Under perfect banking competition, these elasticities are not internalized by banks and hence do not influence the model dynamics or the steady state. However, under imperfect banking competition, banks will respond to the changes in the loan demand elasticity.

Since PED_t (42) only depends on period t variables and expectations, together with $\Lambda_{t,t+1} > 0$ and $\pi_{t+1} \equiv \frac{p_{t+1}}{p_t} > 0$, the first order condition (40) implies that $\left(\frac{\partial R_{b,t}}{\partial b_t}\frac{b_t}{R_{b,t}}\frac{1}{N}+1\right)R_{b,t} = R_t$. It follows that the equilibrium loan rate depends on the policy rate R_t, the number of banks N, and the elasticity of loan demand PED_t:

$$R_{b,t} = \frac{1}{1-\frac{1}{N}PED_t^{-1}}R_t \equiv \mu_t R_t \tag{43}$$

where $\mu_t \equiv \frac{1}{1-\frac{1}{N}PED_t^{-1}}$ is the loan markup. With perfect banking competition, each bank faces a perfectly elastic loan demand, so $NPED_t \to \infty$ and lending rate is identical to the policy rate $R_{b,t} = R_t$. With Cournot competition, banks with market power can affect the equilibrium loan rate by taking advantage of the endogenously changing loan demand elasticity. From (43), the loan markup μ_t decreases in the number of banks N (implying more intense banking competition) and the loan demand elasticity PED_t. For a given level of imperfect banking competition implied by N, changes in the loan demand elasticity over the business cycle will cause the loan markup to change, which then affects aggregate fluctuations.

2.3 Equilibrium Conditions

In equilibrium, the aggregate resource constraint is:

$$c_t + i_t + \frac{\chi}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2 i_t = y_t \tag{44}$$

which is also the goods market clearing condition. In equilibrium, the labor supplied by households equals the firm's labor demand and the new capital supplied by capital producers equals the firm's capital demand. Let b_t^B and d_t^B denote the total units of loans given out and deposits taken in by the banking sector, respectively. Under perfect banking competition with a continuum of banks of unit mass, $b_t^B = \int_0^1 b_t(j)dj$ and $d_t^B = \int_0^1 d_t(j)dj$, while with a Cournot banking sector, $b_t^B = \sum_{j=1}^N b_t(j)$ and $d_t^B = \sum_{j=1}^N d_t(j)$. In equilibrium, the supply of loans from the banking sector b_t^B equals the market loan demand b_t and the demand for deposits from the banking sector d_t^B equals the supply of deposits from households d_t. Based on banks' balance sheet identity, the total loan supply equals the total deposit holding $b_t^B = d_t^B$.

3 Calibration

The two models with different types of banking competition are solved numerically using Dynare after calibrating the parameters to a quarterly frequency. Using the ECB's harmonized monetary financial institutions' (MFI) interest rates from 2000 to 2018, the average annualised household deposit rate is around 2.16%. Hence, the household subjective discount factor β, is set at 0.995, giving an annualised net real deposit rate of $\left(\frac{1}{0.995} - 1\right) * 4 \approx 2\%$.

In order to focus on the role of imperfect banking competition, the gross inflation target π is set to one and the investment adjustment cost parameter χ is set to zero in the baseline analysis so that the price dispersion $f_{3,t}$ (28) and the real capital price q_t (20) remain a constant one. The elasticity of substitution among differentiated retail goods ϵ is chosen to be 6, to generate a final good price markup x over the wholesale good of 20% ($x = \frac{\epsilon}{\epsilon-1}$) in this zero-inflation steady state. The probability θ of retailers keeping prices fixed in each period is set at 0.75 to give a price rigidity of $\frac{1}{1-0.75} = 4$ quarters on average. The calibration for ϵ and θ is in line with the literature (e.g., Andrés and Arce, 2012; Gerali et al., 2010). Using the first order condition with respect to capital (14), the steady state capital to output ratio is:

$$\frac{k}{y} = \frac{\alpha_k}{x(\frac{R_b}{\pi} - 1 + \delta)} \tag{45}$$

where final good output is equal to the wholesale good output $y = y_w$ in a zero-inflation steady state, and the real loan rate $\frac{R_b}{\pi}$ is equal to the real deposit rate $\frac{R}{\pi} = \frac{1}{\beta}$ under perfect banking competition. Given the calibration for β and x, the capital share α_k and depreciation rate δ are calibrated to match the capital to output ratio of 4.9 and the labor share of 0.56, which are mean values for EU countries over 2000-2017 from the Penn World Table (PWT). Assuming a constant-returns-to-scale production function, the average capital share $\alpha_k = 1 - \alpha_l$ is thus 0.44. Suppose $\frac{k}{y}$ is equal to 4.9, setting α_k to 0.44 implies a depreciation rate of 0.07.

Given the calibration for β, ϵ, α_k, α_l and δ, the relative utility weight on leisure time ϕ is set to 1.8 to yield a steady state labor l of around 0.28, which achieves the target of the average annual hours worked by the employed people (i.e., 1756 hours on average across EU countries over 2000-2017 from PWT). Assuming people work for five days a week, 1756 working hours implies people work for around 6.8 hours a day on average and hence the labor time normalized by 24 hours is around 0.28.

The death rate of firms φ governs the amount of dividend paid to households by the exiting firms. Households' transfer of ω fraction of physical capital to new entering firms ensures that these new firms have some initial net worth. From the evolution of aggregate net worth (16), the parameters φ and ω pin down the steady state asset to equity ratio $\frac{k}{n}$:

$$\frac{k}{n} = \frac{1 - (1-\varphi)\frac{R_b}{\pi}}{\omega} \tag{46}$$

where φ is calibrated to match the average annual enterprise death rate of around 10% for EU countries over 2008-2017 from the OECD database. After setting φ to 0.025, meaning that 2.5% of firms exit each quarter, ω is calibrated to match the average asset to equity ratio across non-financial firms in Europe of around 4.7 over 2000-2008, as documented in Kalemli-Ozcan, Sorensen and Yesiltas (2012). Hence, ω is set to 0.0042 to give an asset to equity ratio $\frac{k}{n}$ of around 4.8.

To focus on the model mechanism, the Taylor rule is kept to its simplest form in the baseline analysis. There is no interest rate smoothing ($\rho_r = 0$) and the feedback coefficient on output κ_y is set to zero. Monetary policy only responds to the deviation of the gross inflation rate from the inflation target π, where the feedback coefficient on inflation κ_π is set to 1.5. I also use different calibrations for ρ_r, κ_π and κ_y as robustness checks in Section 5. The standard deviation for the monetary policy shock σ_r is 0.0025 and for the productivity shock σ_z is 0.01. I look at two types of productivity shocks. When the productivity shock has a persistent effect, I set the parameter ψ in the AR(1) process to 0.95. When looking at a fully transitory productivity shock, ψ is set to 0. The parameter κ_π and the shock-related parameters are in line with the literature (e.g., Andrés and Arce, 2012; Gerali et al., 2010).

Table 1: Calibration of Parameters in Baseline Analysis

Parameter	Value	Description
Households		
β	0.995	Subjective discount factor
ϕ	1.8	Relative utility weight on leisure time
Firms		
α_k	0.44	Physical capital share
δ	0.07	Depreciation rate for physical capital
φ	0.025	Death rate of firms
ω	0.0042	Transfer from households to new firms
Capital producers		
χ	0	Investment adjustment cost
Retailers		
ϵ	6	Elasticity of substitution between retail goods
θ	0.75	Probability of not adjusting price
Banking sector		
N	4	Number of banks
Central bank		
ρ_r	0	Interest rate smoothing
κ_π	1.5	Feedback coefficient on inflation
κ_y	0	Feedback coefficient on output
Shocks		
σ_r	0.0025	Standard deviation of monetary policy shock
σ_z	0.01	Standard deviation of productivity shock

Given the calibration for β, ϵ, α_k, δ, φ and ω, the number of banks N is set to 4 to get a steady-state gross loan rate R_b of 1.01, implying an annualised net real loan rate of $(1.01 - 1) * 4 \approx 4\%$ and a real loan margin of around 200 basis points. This matches the average annualised corporate loan rate of around 4.14% and the loan interest margin of around 198 basis points across EU countries over the past 19 years, using the ECB's harmonized monetary financial institutions' (MFI) interest rates from 2000 to 2018. Table 1 summarizes the calibrated parameters discussed above, which are used for the baseline analysis. Under this calibration, the steady state values of the key variables can be found in Table 2 in Appendix C.

With imperfect banking competition, a higher loan rate lowers the capital to output ratio (45) and the asset to equity ratio (46), among other variables, as shown in Table 2 in Appendix C. When comparing the dynamics of the two models with different types of banking competition in Section 4, I assume that there is a lump sum tax that redistributes the positive profit from the banking sector to households such that the steady state under imperfect banking competition is identical to that under perfect banking competition.

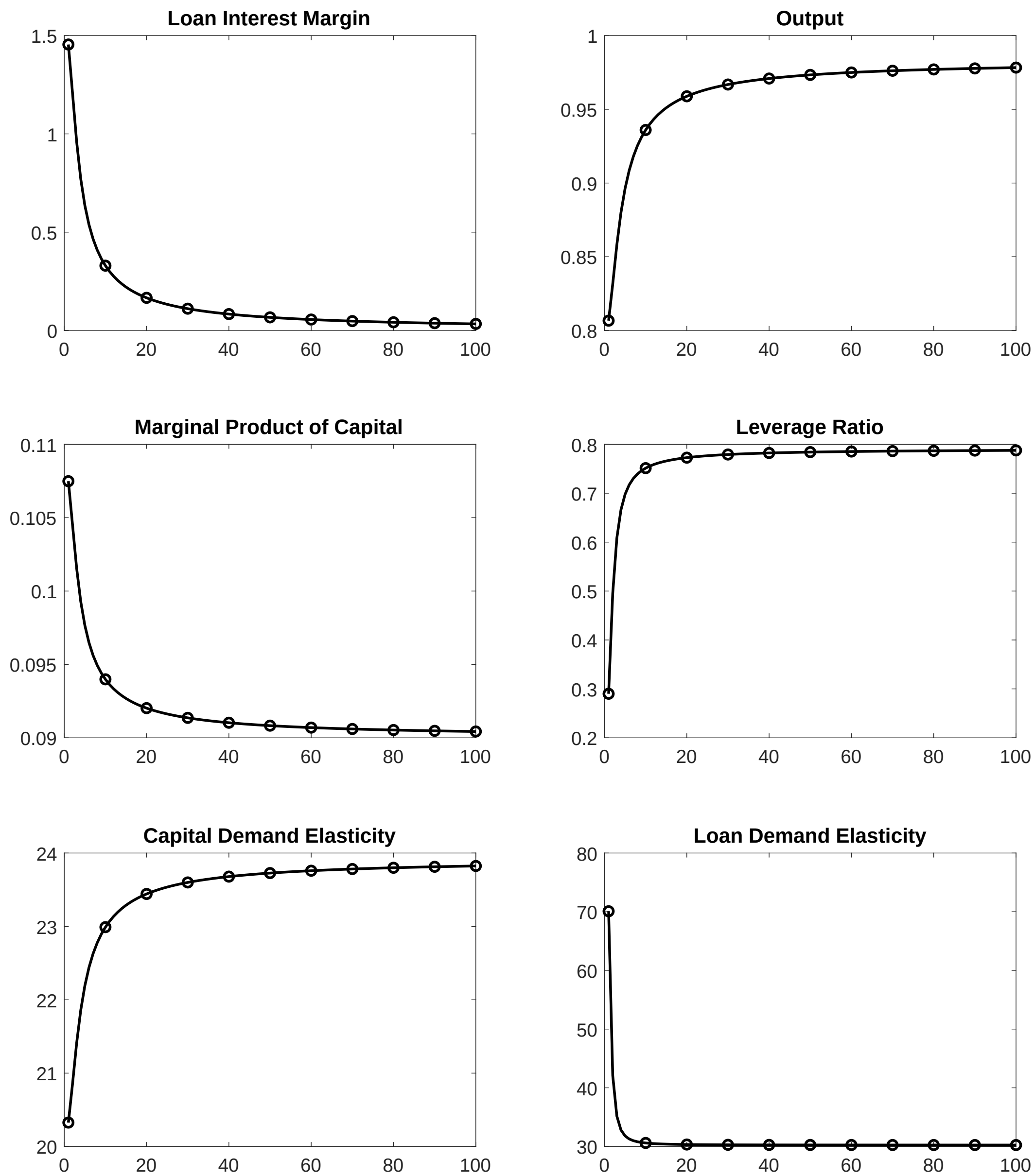
Figure 1 plots the steady state values for some variables against the number of banks N that ranges from 1 to 100. A higher N implies more intense competition. When there is a monopoly bank, the annualised loan margin is around 150*4 = 600 basis points. As N increases, the loan margin $(R_b - R)$ approaches zero and output increases.

From (43), the equilibrium loan rate decreases in the number of banks, as well as the interest rate elasticity of loan demand. One key component that determines the loan demand elasticity is the capital demand elasticity. From (41), capital demand is more elastic when the marginal product of capital is lower. Under the assumption of a constant-returns-to-scale production function, the marginal product of capital $\alpha_k z \left(\frac{k}{l}\right)^{\alpha_k - 1}$ decreases in the capital to labor ratio. As the number of banks N increases, a lower loan rate makes capital cheaper relative to labor, raising the capital to labor ratio and thus reducing the marginal product of capital. Hence, Figure 1 shows that as N increases, capital demand elasticity also increases.

If capital were financed by bank loans only, then the loan demand elasticity would be identical to the capital demand elasticity. However, capital is financed by both bank loans and net worth, so the loan demand elasticity also depends on firms' leverage ratio $\frac{b}{qk} = \frac{qk-n}{qk}$ (42). Figure 1 shows that despite the capital demand becoming more elastic, the loan demand is more inelastic due to a higher leverage ratio as N increases. A higher leverage ratio implies greater reliance on bank loans, which tends to make the loan demand more inelastic. As N increases, the firm's net worth n falls as a lower loan rate reduces the benefit of using internal financial (net worth) relative to external financing and slows down the net worth accumulation. As a result, the leverage ratio rises as N increases, which tends to make the loan demand more inelastic.

Figure 1 shows that in the long-run equilibrium, the loan rate is mainly driven by the number of banks N instead of the market loan demand elasticity. A higher N directly reduces the equilibrium loan rate and thus the loan interest margin, although it is associated with a more inelastic loan demand. The next section shows that conditional on the number of

Figure 1: Steady State Values for Different Number of Banks



Note: The figure shows the steady state values of variables against the number of banks N ranging from 1 to 100. The loan margin is expressed in percent points. The marginal product of capital is computed as $\alpha_k z k^{\alpha_k - 1} l^{\alpha_l}$ and the leverage ratio refers to the loan to asset ratio $\frac{b}{qk}$.

banks, endogenous changes in the loan demand elasticity in response to shocks can drive the changes in the loan interest margin over the business cycle.

4 Dynamic Analysis

In this section, I investigate how aggregate output responds to a monetary policy shock, a persistent productivity shock, and a transitory productivity shock under imperfect and perfect banking competition. To compare models with different types of banking competition, I assume that the government taxes the steady steady profit made by the banking sector and transfers it to households, so the two models have the same steady state. This nonlinear model is solved using a first-order Taylor approximation around the steady state in Dynare.

4.1 Monetary Policy Shock

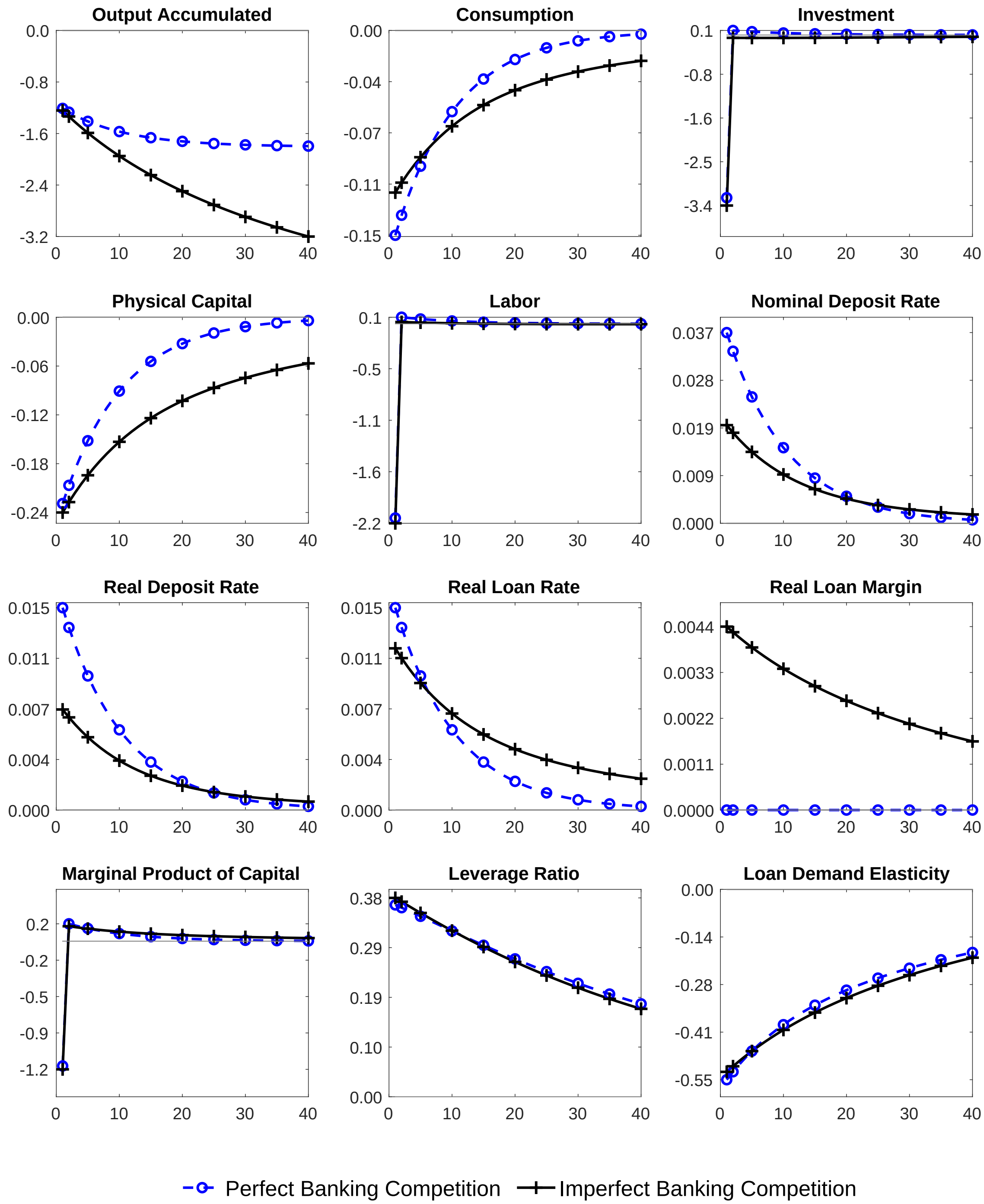
Figure 2 shows the impulse responses to an unexpected one-time monetary policy shock, where the white noise term $e_{r,t}$ in the Taylor rule is raised by 25 basis points at the beginning of period 1. The nominal deposit rate or the policy rate increases as a consequence.

Under perfect banking competition, output decreases by around 1.2% immediately after a contractionary monetary policy shock, but quickly rises back to the steady state. As a result, the output accumulated flattens and the total percentage deviation of output from its steady state is only around 1.8% in period 40. However, under imperfect banking competition, accumulated output is 3.2% lower than its steady state in period 40, which is around 78% higher relative to perfect banking competition. This amplification effect of imperfect banking competition can be explained by a rise in the real loan margin.

With perfect banking competition, households and firms face the same real interest rate, and thus the loan interest margin $(R_{b,t} - R_t)$ is zero. A higher real loan rate $\frac{R_{b,t}}{\pi_{t+1}}$ after the contractionary monetary policy shock reduces firms' demand for capital and output. The reduction in output leads to a lower consumption. As consumption rises towards the steady state (i.e., $c_{t+1} > c_t$), the real interest rate is high during this transition to signal to households to save more for future consumption. Households' savings are channelled into financing firms' capital input for production. When households save more, capital stock is gradually built up and output recovers.

The dynamics of the real interest rate reflect the intertemporal substitution of consumption. They also govern the dynamics of the expected marginal product of capital as firms choose their optimal capital to equate the expected marginal return on capital to the real interest rate (12). Combining the Euler equation (6) and the firm's first order condition with

Figure 2: Impulse Responses to a Contractionary Monetary Policy Shock



Note: Horizontal axis shows quarters after a contractionary monetary policy shock of 25 basis points at the beginning of period 1. Vertical axis shows the percentage deviation from the steady state for variables other than the interest rates and the loan margin, which are expressed in deviations from the steady state in percent points. Leverage ratio refers to the debt-to-asset ratio $\frac{b_t}{q_t k_t}$ and marginal product of capital is $\frac{\alpha_k y_t}{k_{t-1}}$.

respect to capital (12) gives:

$$1 = \beta E_t \left[\frac{c_t}{c_{t+1}} \frac{R_t}{\pi_{t+1}} \right] = \beta E_t \left[\frac{c_t}{c_{t+1}} \frac{(MPK_{t+1} + q_{t+1}(1-\delta))}{q_t} \right] \tag{47}$$

where the deposit rate $\frac{R_t}{\pi_{t+1}}$ equals the loan rate $\frac{R_{bt}}{\pi_{t+1}}$ under perfect banking competition and $MPK_{t+1} = \frac{\alpha_k z_{t+1} k_t^{\alpha_k - 1} l_{t+1}^{\alpha_l}}{x_{t+1}}$ is the marginal product of capital in real (final consumption) terms. This section assumes there is no investment adjustment cost so that $q_t = q_{t+1} = 1$. From (47), when the expected return to capital is higher, households want to consume less and save more today.

Figure 2 shows a higher marginal product of capital from period 2 onwards. Since capital is predetermined, the initial drop in marginal product of capital in Figure 2 is caused by the drop in labor hours. A higher expected marginal product of capital makes the capital demand less sensitive to the loan rate (41). Since capital is partially financed by bank loans, the loan demand also becomes more inelastic. In addition, the rise in firms' leverage ratio $\frac{b_t}{q_t k_t}$ implies that firms rely more on bank loans, which also tends to make their loan demand more inelastic. Figure 2 shows that the loan demand elasticity PED_t falls by 0.55% immediately after the shock, which is due to a higher expected marginal product of capital and a higher leverage ratio.

Under perfect banking competition, despite the market loan demand becoming more inelastic, each bank faces a perfectly elastic loan demand and takes the equilibrium loan rate as given. By contrast, when banks have market power, they can take advantage of the lower loan demand elasticity by reducing the quantity of loans to achieve a higher equilibrium loan rate. The higher real loan rate then reduces the firms' demand for capital and therefore output by more. However, Figure 2 shows that the real loan rate under imperfect banking competition is initially lower than that under perfect banking competition. This suggests that the slight amplification effect during the early periods is likely driven by other forces.

Apart from amplifying the reduction in capital through a higher loan rate, imperfect banking competition also distorts households' consumption-saving decisions through a lower deposit rate. Figure 2 shows that the real deposit rate under imperfect banking competition is much lower relative to the perfect banking competition benchmark during the early periods.

Under imperfect banking competition, the relative price of consumption today is distorted by the markup of loan rate over deposit rate $\mu_t \equiv \frac{R_{b,t}}{R_t}$:

$$1 = \beta E_t \left[\frac{c_t}{c_{t+1}} \frac{R_{b,t}}{\pi_{t+1} \mu_t} \right] = \beta E_t \left[\frac{c_t}{c_{t+1}} \frac{(MPK_{t+1} + q_{t+1}(1-\delta))}{\mu_t q_t} \right] \tag{48}$$

where the loan markup $\mu_t = \frac{1}{1-\frac{1}{N}PED_t^{-1}}$ (43) increases if the loan demand becomes more inelastic (i.e., lower PED_t). As the number of banks N approaches infinity and the banking sector becomes perfectly competitive, this loan markup is one. With a small number of banks, any change in the loan demand elasticity induces banks to optimally adjust their markups. When the expected return on capital is higher, the loan demand becomes more inelastic and the loan markup μ_t is larger. Instead of getting the expected return on capital by saving more today, households can only get a fraction $\frac{1}{\mu_t}$ of that expected return. Figure 2 shows that the fall in consumption in period 1 is smaller under imperfect banking competition, indicating that households are not saving enough due to the distorted expected return from saving. As a result, investment and capital drop by more for a reduction in output of similar sizes (as changes in the real loan rate between the two types of banking competition during the initial periods are similar).

Due to the capital accumulation process, a higher loan rate under imperfect banking competition is able to have a persistent effect on capital stock and output as time passes. Since the response of capital at any given point in time is the accumulated responses of past investment, lower investment under imperfect banking competition at each point in time slows down the capital accumulation, leading to a more persistent reduction in output.

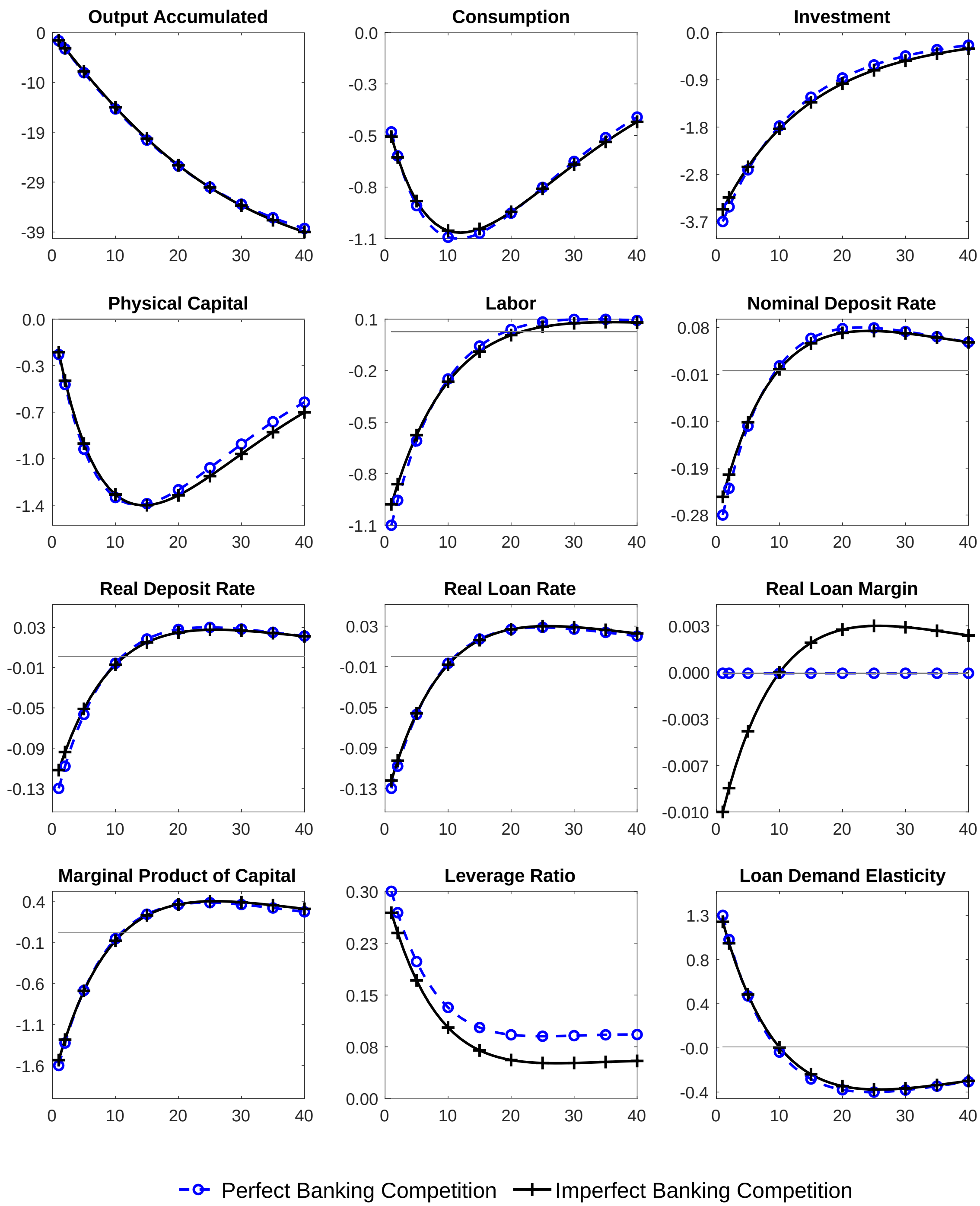
4.2 Productivity Shocks

Figure 3 shows the impulse responses after a persistent negative productivity shock. Under imperfect banking competition, output is initially attenuated but amplified later on, so the output accumulated is slightly larger in later periods. The differential responses of output under the two types of banking competition can be explained by changes in the real loan margin. The dynamics of the expected marginal product of capital is a key factor that drives the loan demand elasticity and hence the loan margin.

Unlike the monetary policy shock, there are now two opposite forces that act upon the expected marginal product of capital. On the one hand, a persistently low productivity directly reduces the expected marginal product of capital. On the other hand, there is an upward pressure on the real interest rate to induce households to save for future consumption so that consumption can rise towards its steady state. More savings ensure that capital stock can be gradually built up and output eventually recovers. Initially, the effect of the lower productivity dominates, so the expected marginal product of capital falls. Later on, as productivity rises towards its steady state, the upward pressure on the real interest rate and the expected return on capital dominates.

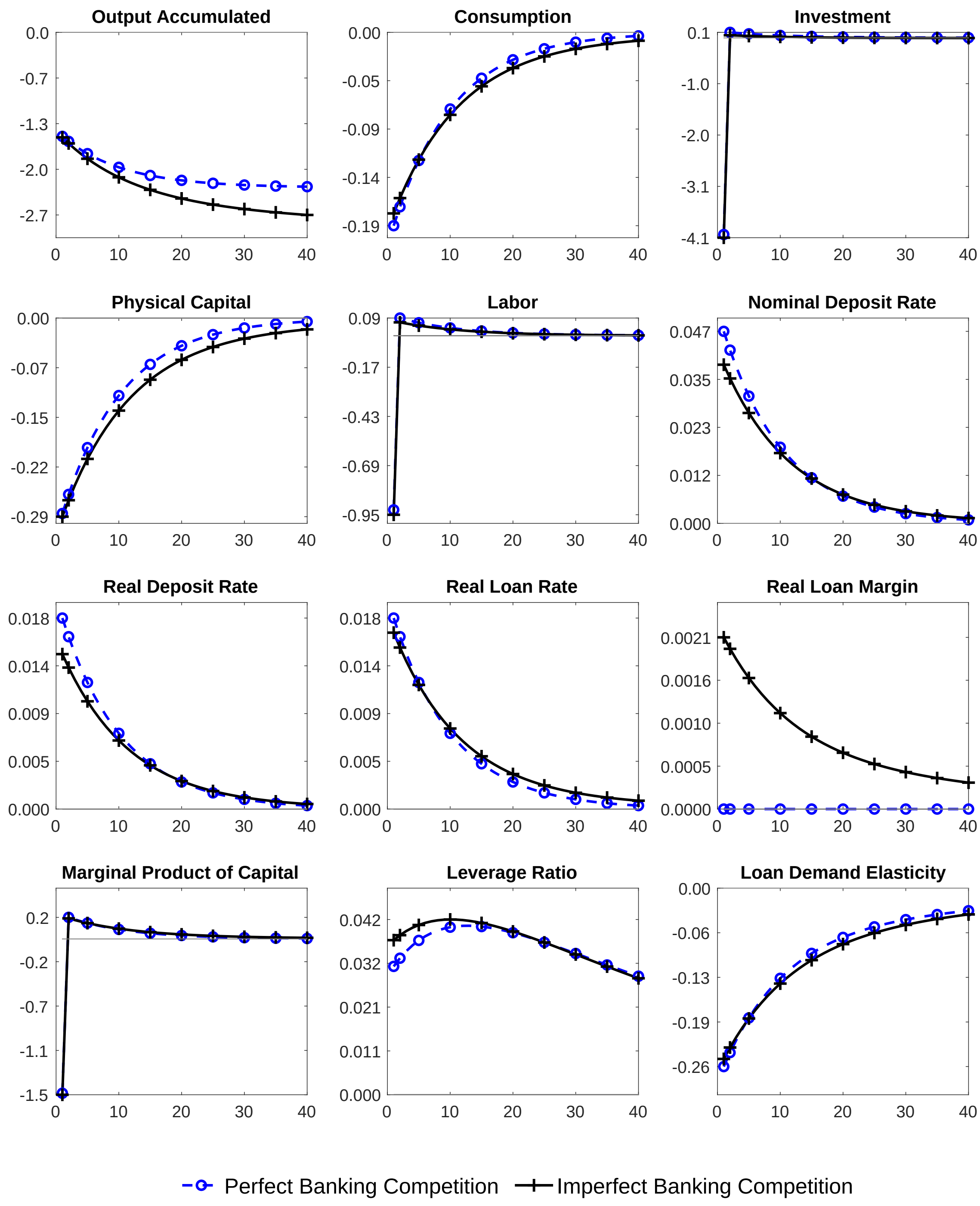
Consequently, the expected marginal product of capital is lower during the early periods

Figure 3: Impulse Responses to a Persistent Negative Productivity Shock



Note: Horizontal axis shows quarters after a one-standard-deviation negative productivity shock at the beginning of period 1. The shock has a persistent effect as productivity follows an AR(1) process with a persistence parameter $\psi = 0.95$. Vertical axis shows the percentage deviation from the steady state for variables other than the interest rates and the loan margin, which are expressed in deviations from the steady state in percent points. Leverage ratio refers to the debt-to-asset ratio $\frac{b_t}{q_t k_t}$ and marginal product of capital is $\frac{\alpha_k y_t}{k_{t-1}}$.

Figure 4: Impulse Responses to a Transitory Negative Productivity Shock



Note: Horizontal axis shows quarters after a one-standard-deviation negative productivity shock at the beginning of period 1. The persistence parameter ψ in the AR(1) process for productivity is set to zero, so the shock is fully transitory. Vertical axis shows the percentage deviation from the steady state for variables other than the interest rates and the loan margin, which are expressed in deviations from the steady state in percent points. Leverage ratio refers to the debt-to-asset ratio $\frac{b_t}{q_t k_t}$ and marginal product of capital is $\frac{\alpha_k y_t}{k_{t-1}}$.

and is higher later on, making the capital demand initially more elastic but later on inelastic. In the model, capital is partially financed by loans, so changes in capital demand elasticity map into the loan demand elasticity. With imperfect banking competition, banks have market power and take into account the changing loan demand elasticity when choosing their loan quantities. They respond to a lower loan demand elasticity by reducing their loan quantities to achieve a higher equilibrium loan rate and vice versa. Since the loan demand becomes more elastic initially and more inelastic later on, the real loan margin is initially procyclical and turns countercyclical during later periods.

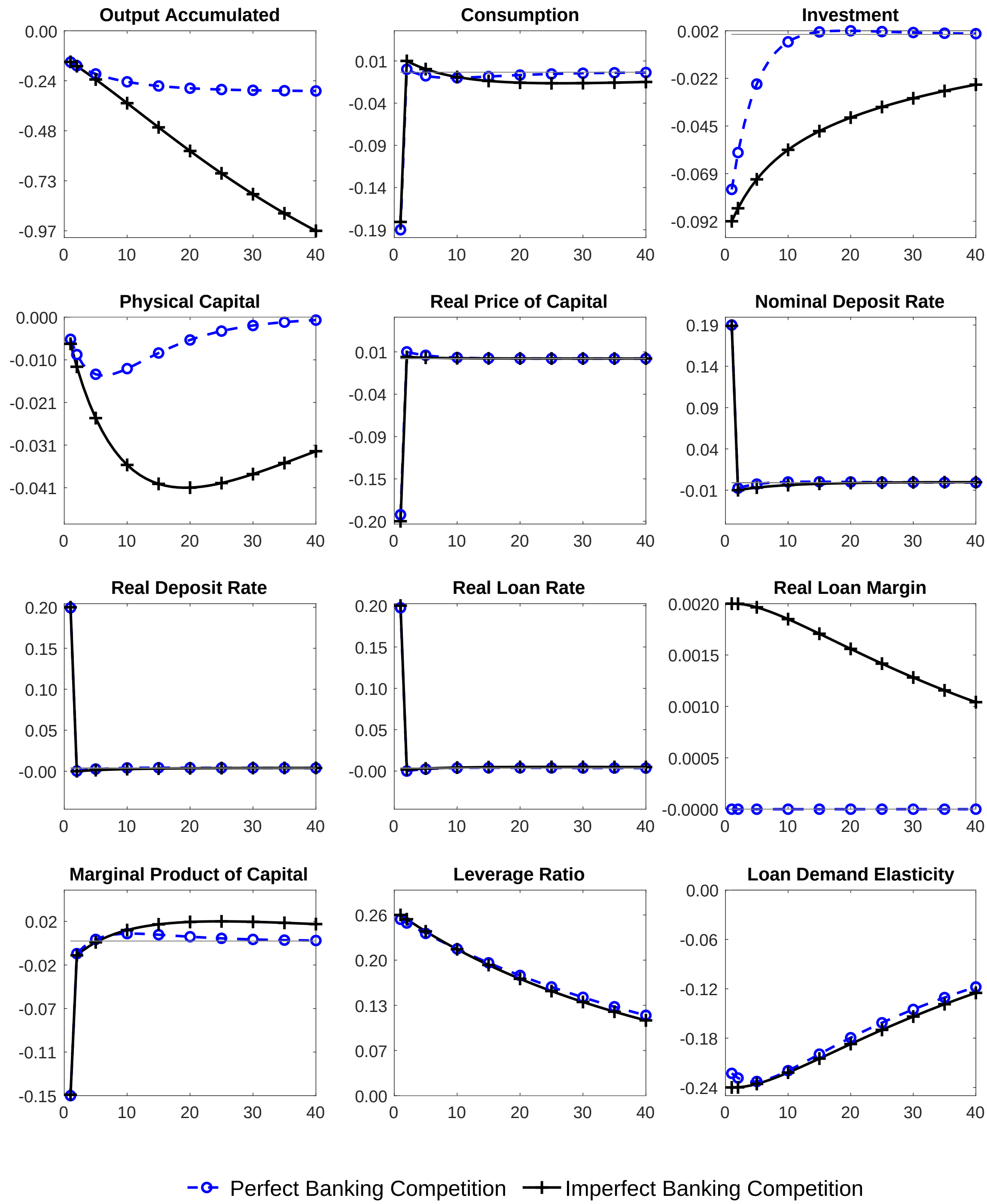
In contrast to the persistent productivity shock, Figure 4 shows that output accumulated is around 17% lower under imperfect banking competition after a transitory negative productivity shock. I assume the productivity no longer follows an AR(1) process in this case. Productivity falls at the beginning of period 1 and returns to its steady state the next period. As a result, the marginal product of capital falls in the first period due to lower productivity z_t and labor hours l_t, but rises immediately after due to a higher real interest rate, unlike after a persistent productivity shock where continuously low productivity tends to drive down the expected marginal product of capital. A higher expected marginal product of capital and a higher leverage ratio make the loan demand more inelastic, leading to a fall in the loan demand elasticity PED_t in Figure 4. Under imperfect banking competition, banks respond to the more inelastic loan demand by reducing their loan quantities to achieve a higher loan rate, leading to a rise in the real loan margin. A higher loan rate relative to the perfect banking competition benchmark reduces the firms' capital demand by more and thus amplifies the drop in output.

Despite a rise in the real loan margin, the real loan rate under imperfect banking competition is initially lower. The intertemporal substitution channel may explain why capital is still amplified during early periods. When expected return on capital is higher, households want to postpone their consumption and save more under perfect banking competition. However, a higher expected return on capital also implies a higher loan markup μ_t under imperfect banking competition, which reduces the expected return from saving as households can only receive a fraction $\frac{1}{\mu_t}$ of the higher expected expected return on capital. Therefore, households do not save as much relative to perfect banking competition, leading to a greater reduction in investment and capital.

5 Sensitivity Analysis

I check the robustness of the baseline results in Section 4 by changing the investment adjustment cost parameter χ, the number of banks N, the output elasticities of capital α_k and

Figure 5: Impulse Responses to a Contractionary Monetary Policy Shock when $\chi = 2$



Note: Horizontal axis shows quarters after a contractionary monetary policy shock of 25 basis points at the beginning of period 1. Vertical axis shows the percentage deviation from the steady state for variables other than the interest rates and the loan margin, which are expressed in deviations from the steady state in percent points. Leverage ratio refers to the debt-to-asset ratio $\frac{b_t}{q_t k_t}$ and marginal product of capital is $\frac{\alpha_k y_t}{k_{t-1}}$.

labor α_l, the depreciation rate δ, the initial transfer from households ω, and the parameters in the Taylor rule (ρ_r, κ_π, and κ_y), while each time, all the other parameters are calibrated as in the baseline analysis. This section discusses the sensitivity of the baseline results to these parameters in turn.

In the baseline analysis in Section 4, I assume there is no investment adjustment cost (i.e., $\chi = 0$) so that the real price of capital is always one. In the presence of investment adjustment cost, the dynamics of consumption, investment, capital are quite different. Comparing Figure 5 with Figure 2, due to the adjustment cost, capital no longer adjusts instantly in response to the contractionary monetary policy shock. In fact, the initial drop in capital is very small. The response of investment is smoothed and changes in investment become much smaller, which reduces households' ability to smooth consumption. As a result, consumption is more volatile and moves more closely with the output. The smaller fall in investment and capital leads to a smaller drop in output. Figure 5 shows that the initial drop in output is only around 0.2%, whereas output drops by 1.2% if capital could adjust immediately in Figure 2.

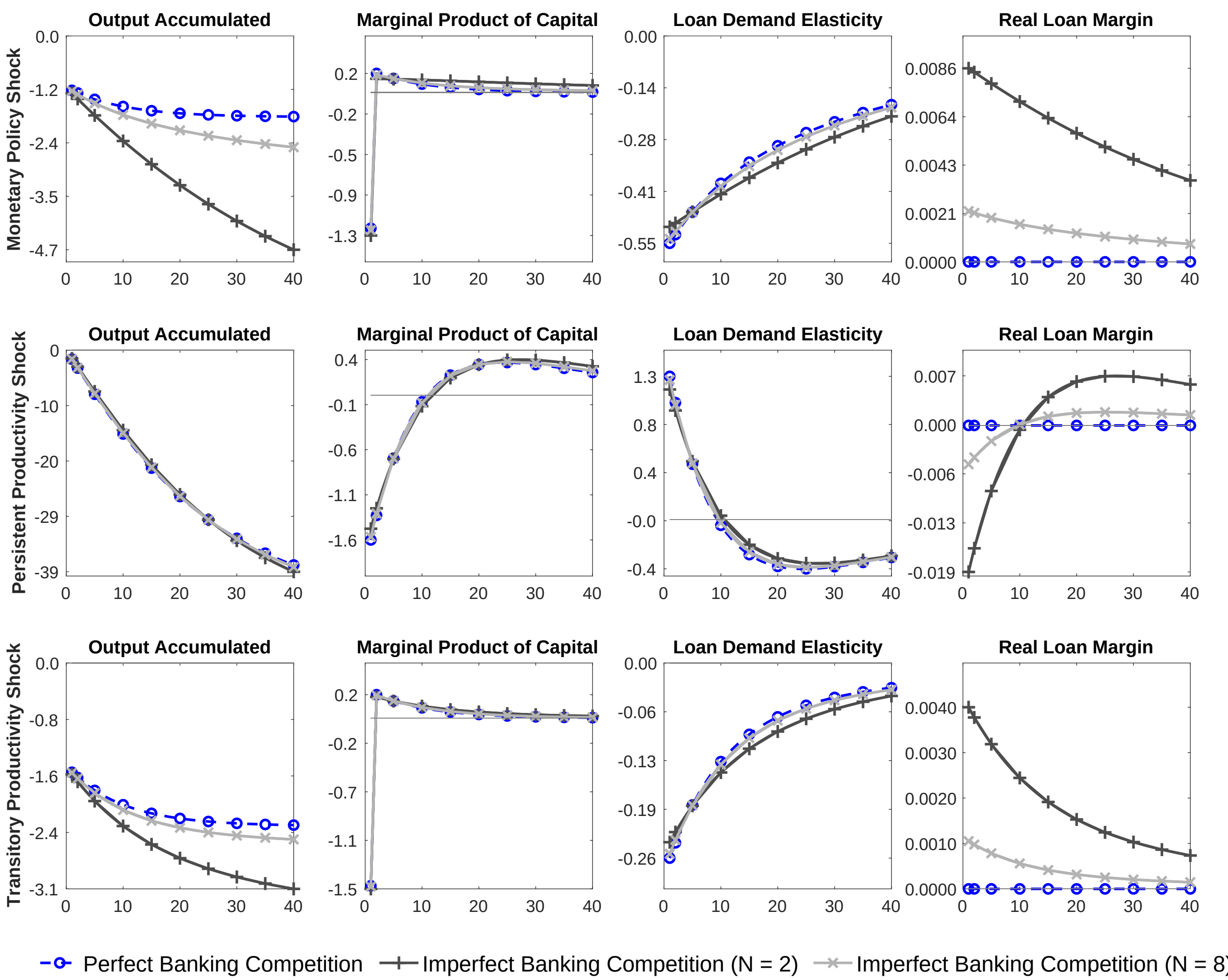
In the presence of investment adjustment cost, imperfect banking competition greatly slows down capital accumulation compared to the perfect banking competition benchmark. As a result, the drop in output is much more persistent and even after 40 quarters, output is still far from reaching the steady state. Figure 5 shows that accumulated drop in output under imperfect banking competition is almost 4 times the accumulated drop under perfect banking competition in period 40. This is because the higher loan rate under imperfect banking competition now has a more persistent effect on output via the smoothed investment process in addition to capital accumulation.

After a persistent productivity shock, the results are similar to Figure 3 and there is not much difference between the two types of banking competition. When the productivity shock is fully transitory, there is very little change in capital and thus changes in the expected marginal product of capital are minimal. Figure 7 shows that in the presence of investment adjustment cost, firms' leverage ratio can decrease in this case,[11] making the loan demand more elastic and leading to a procyclical loan markup that attenuates the output.

Figure 6 shows the impulse responses of output, marginal product of capital, loan demand elasticity PED_t, and the real loan margin after three types of shocks when the number of banks N is two, eight and infinity (i.e., perfect competition). When there are only two banks, the amplification effect is much larger after the contractionary monetary policy shock and the transitory productivity shock. After a persistent productivity shock, it is still difficult to

[11]This is because firms' net worth increases due to a higher capital price and hence a higher value of undepreciated capital. So borrowing ($b_t = q_t k_t - n_t$) falls more than the value of capital, leading to a drop in leverage ratio $\frac{b_t}{q_t k_t}$.

Figure 6: Impulse Responses for Different Shocks and Number of Banks N



Note: Horizontal axis shows quarters after the shock that occurs at the beginning of period 1. Vertical axis shows the percentage deviation from the steady state for variables other than the loan margin, which is expressed in deviations from the steady state in percent points. Each row shows the impulse responses of four variables after a given type of shock: a 25 basis-point contractionary monetary policy shock, a one-standard-deviation persistent negative productivity shock ($\psi = 0.95$), and a one-standard-deviation transitory negative productivity shock ($\psi = 0$).

see the differences clearly since output is initially attenuated but later on amplified. When N increases to eight, banks' market power is greatly reduced and the outcome is closer to the perfect banking competition benchmark.

Reducing the output elasticity of capital α_k from 0.44 to 0.25 gives a slightly stronger amplification effect of imperfect banking competition. This is because a lower α_k implies that capital is used less intensively in the production, so the reduction in capital is larger after the negative shocks, which is associated with a higher expected marginal product of capital. The latter leads to a more inelastic loan demand and a higher loan interest margin that amplifies output. Figure 8 in Appendix D shows that the magnitude of the rise in loan interest margin is larger compared to the baseline results in Section 4.

Changing the depreciation rate δ will change the steady state value of the loan demand elasticity PED. Using (41) and (42),

$$PED = \frac{1}{1-\alpha_k}\left(1+\frac{1-\delta}{MPK}\right)\frac{qk}{b} \tag{49}$$

where $q = 1$ and $MPK = \frac{z\alpha_k k^{\alpha_k-1}l^{\alpha_l}}{x} = \frac{R_b}{\pi} - 1 + \delta$ (12). A higher depreciation rate δ directly lowers PED and indirectly through raising the steady state marginal product of capital in final consumption units MPK. Similarly, changing the parameter ω that governs the transfer from households to new entering firms also affects PED through the leverage ratio $\frac{b}{qk}$. From (46), a lower ω leads to a lower total net worth n of firms and a higher asset to equity ratio $\frac{k}{n}$. Since $b = k - n$, the leverage ratio $\frac{b}{k} = (1 - \frac{n}{k})$ is also higher, which leads to a more inelastic loan demand in the steady state (49).

A lower steady state value of loan demand elasticity leads to a larger percentage deviation of loan demand elasticity from its steady state PED and thus a larger change in the loan margin. Figure 9 and Figure 10 in Appendix D show that when the depreciation rate δ and the initial transfer from households ω are lower relative to the baseline calibration, the rise in the loan margin is smaller and hence the amplification effect of imperfect banking competition is weaker in the former case, whereas the opposite happens in the latter case.

The baseline results are robust to changing the interest rate smoothing parameter ρ_r. In the baseline analysis, the Taylor rule (35) takes the simplest possible form where both ρ_r and the feedback coefficient on output κ_y are set to zero. When changing ρ_r to 0.7, the contractionary monetary policy shock leads to a persistent increase in the nominal interest rate due to interest rate smoothing, thus increasing the effective size of the shock. Figure 11 in Appendix D shows that the responses of output under both types of banking competition are much larger when $\rho_r = 0.7$.

Increasing κ_π leads to a greater response to the deviation of inflation from its target.

Figure 12 in Appendix D shows that the fall in output is smaller under both types of banking competition after the contractionary monetary policy shock that is deflationary, but larger after the negative transitory productivity shock that is inflationary. In the latter case, the real loan rate rises more to bring down inflation, causing a larger fall in output.

However, the amplification effect after a transitory productivity shock in the baseline analysis is not robust to changes in the sensitivity κ_y of the policy rate to the output gap, for a given calibration of $\kappa_\pi = 1.5$. This is because after the negative productivity shock, the fall in output is large. With $\kappa_y > 0$, the central bank's response to the output gap leads to a lower policy rate, and thereby a lower real loan rate. This leads to a smaller reduction in firms' net worth and a lower leverage ratio that tends to make the loan demand more elastic. Figure 13 in Appendix D shows that when $\kappa_y = 0.125$, the loan demand becomes more elastic and the loan margin decreases after a negative transitory productivity shock.

6 Conclusions

By developing a DSGE framework that features a Cournot banking sector, this paper finds that imperfect banking competition can be an important propagation mechanism for macroeconomic shocks even in a general framework. The amplification effect in this paper works through the general equilibrium dynamics in the expected marginal product of capital. I find that when the expected return on capital is higher, firms' capital demand is less sensitive to the loan rate. Since capital is financed by bank loans and firms' net worth, when capital demand is more inelastic, loan demand also becomes more inelastic. Banks with market power will respond to the lower loan demand elasticity by charging a higher loan markup, which reduces firms' capital demand and output by more relative to perfect banking competition.

Since different shocks lead to different dynamics of the expected marginal product of capital, this paper finds that the cyclicality of the loan markup is shock-specific. After a contractionary monetary policy shock, a higher real interest rate leads to a drop in output and consumption. As consumption rises back towards the steady state, the real interest rate remains high to induce households to save for future consumption. Under perfect banking competition, the higher real interest rate reflects a higher expected marginal return from capital, as firms choose their optimal capital to equate the two. A higher expected return on capital implies a more inelastic capital and loan demand, which leads to a larger loan markup that amplifies the reduction in output.

The results in this paper provide implications for monetary policy. With imperfect banking competition, monetary policy can have a greater impact on the real economy via a countercyclical loan markup. As a result, when policymakers decide by how much to raise the policy rate, it is important to factor in the amplification effect from imperfect banking competition.

Appendices

A Elasticities of Capital and Loan Demand

Differentiate the optimal capital demand (12):

$$k_t = \left(\frac{E_t \Lambda_{t,t+1} \left[\frac{R_{b,t} q_t}{\pi_{t+1}} - q_{t+1}(1-\delta) \right]}{E_t \Lambda_{t,t+1} \left[\frac{z_{t+1} \alpha_k l_{t+1}^{\alpha_l}}{x_{t+1}} \right]} \right)^{-\frac{1}{1-\alpha_k}} \tag{50}$$

with respect to the loan rate $R_{b,t}$:

$$\begin{aligned} \frac{\partial k_t}{\partial R_{b,t}} &= -\frac{1}{1-\alpha_k} \left(\frac{E_t \Lambda_{t,t+1} \left[\frac{R_{b,t} q_t}{\pi_{t+1}} - q_{t+1}(1-\delta) \right]}{E_t \Lambda_{t,t+1} \left[\frac{z_{t+1} \alpha_k l_{t+1}^{\alpha_l}}{x_{t+1}} \right]} \right)^{-\frac{2-\alpha_k}{1-\alpha_k}} \frac{E_t \Lambda_{t,t+1} \left[\frac{q_t}{\pi_{t+1}} \right]}{E_t \Lambda_{t,t+1} \left[\frac{z_{t+1} \alpha_k l_{t+1}^{\alpha_l}}{x_{t+1}} \right]} \\ &= -\frac{1}{1-\alpha_k} k_t^{2-\alpha_k} \frac{E_t \Lambda_{t,t+1} \left[\frac{q_t}{\pi_{t+1}} \right]}{E_t \Lambda_{t,t+1} \left[\frac{z_{t+1} \alpha_k l_{t+1}^{\alpha_l}}{x_{t+1}} \right]} < 0 \end{aligned} \tag{51}$$

where the second step uses the capital demand (12).

Using (12), (14) and (51), the interest rate elasticity of capital demand PEK_t is:

$$\begin{aligned} PEK_t \equiv -\frac{\partial k_t}{\partial R_{b,t}} \frac{R_{b,t}}{k_t} &= \frac{1}{1-\alpha_k} k_t^{1-\alpha_k} \frac{E_t \Lambda_{t,t+1} \left[\frac{R_{b,t} q_t}{\pi_{t+1}} \right]}{E_t \Lambda_{t,t+1} \left[\frac{z_{t+1} \alpha_k l_{t+1}^{\alpha_l}}{x_{t+1}} \right]} \\ &= \frac{1}{1-\alpha_k} \frac{E_t \Lambda_{t,t+1} \left[\frac{R_{b,t} q_t}{\pi_{t+1}} \right]}{E_t \Lambda_{t,t+1} \left[\frac{R_{b,t} q_t}{\pi_{t+1}} - q_{t+1}(1-\delta) \right]} \\ &= \frac{1}{1-\alpha_k} \frac{E_t \Lambda_{t,t+1} \left[MPK_{t+1} + q_{t+1}(1-\delta) \right]}{E_t \Lambda_{t,t+1} \left[MPK_{t+1} \right]} \\ &= \frac{1}{1-\alpha_k} \left(1 + \frac{E_t \Lambda_{t,t+1} \left[q_{t+1}(1-\delta) \right]}{E_t \Lambda_{t,t+1} \left[MPK_{t+1} \right]} \right) > 0 \end{aligned} \tag{52}$$

where $MPK_{t+1} \equiv \frac{z_{t+1} \alpha_k k_t^{\alpha_k - 1} l_{t+1}^{\alpha_l}}{x_{t+1}}$ denotes the marginal product of capital in real (final consumption) terms and $E_t \Lambda_{t,t+1} \left[\frac{R_{b,t} q_t}{\pi_{t+1}} \right] = E_t \Lambda_{t,t+1} \left[MPK_{t+1} + q_{t+1}(1-\delta) \right]$ comes from the first order condition (12).

Since net worth is unaffected by the current period loan rate, differentiate the market loan demand b_t (15) with respect to the loan rate $R_{b,t}$ to get:

$$\frac{\partial b_t}{\partial R_{b,t}} = q_t \frac{\partial k_t}{\partial R_{b,t}} \tag{53}$$

Hence, the elasticity PED_t of the market loan demand to the loan rate is:

$$PED_t \equiv -\frac{\partial b_t}{\partial R_{b,t}} \frac{R_{b,t}}{b_t} = -\frac{\partial k_t}{\partial R_{b,t}} \frac{R_{b,t}}{k_t} \frac{q_t k_t}{b_t} = PEK_t \frac{q_t k_t}{b_t} > 0 \tag{54}$$

which increases in the capital demand elasticity PEK_t and the inverse leverage ratio $\frac{q_t k_t}{b_t}$.

B Calvo Pricing

B.1 Optimal Pricing Equation

Substitute in $y^*_{t+s}(j)$ and rearrange:

$$Max_{p^*_t(j)} \quad \sum_{s=0}^{\infty} \theta^s E_t \left[\Lambda_{t,t+s} \left(\frac{p^*_t(j)}{p_{t+s}} - \frac{1}{x_{t+s}} \right) \left(\frac{p^*_t(j)}{p_{t+s}} \right)^{-\epsilon} y_{t+s} \right] \tag{55}$$

Take the first order condition:

$$\sum_{s=0}^{\infty} \theta^s E_t \Lambda_{t,t+s} \left[\left(\frac{1}{p_{t+s}} \right) \left(\frac{p^*_t(j)}{p_{t+s}} \right)^{-\epsilon} y_{t+s} + \left(\frac{p^*_t(j)}{p_{t+s}} - \frac{1}{x_{t+s}} \right) (-\epsilon) \left(\frac{p^*_t(j)}{p_{t+s}} \right)^{-\epsilon-1} \frac{y_{t+s}}{p_{t+s}} \right] = 0 \tag{56}$$

Simplify the above equation:

$$\sum_{s=0}^{\infty} \theta^s E_t \Lambda_{t,t+s} \left[(1-\epsilon) \left(\frac{y_{t+s}}{p_{t+s}} \right) \left(\frac{p^*_t(j)}{p_{t+s}} \right)^{-\epsilon} + \epsilon \frac{1}{x_{t+s}} p^*_t(j)^{-\epsilon-1} \left(\frac{1}{p_{t+s}} \right)^{-\epsilon} y_{t+s} \right] = 0 \tag{57}$$

Multiply by $\frac{p^*_t(j)^{\epsilon+1}}{1-\epsilon}$:

$$\sum_{s=0}^{\infty} \theta^s E_t \Lambda_{t,t+s} \left[p^*_t(j) \left(\frac{1}{p_{t+s}} \right)^{1-\epsilon} y_{t+s} + \frac{\epsilon}{1-\epsilon} \frac{1}{x_{t+s}} \left(\frac{1}{p_{t+s}} \right)^{-\epsilon} y_{t+s} \right] = 0 \tag{58}$$

Rearrange to solve for $p^*_t(j)$ and get the optimal pricing equation (26):

$$p^*_t(j) = \frac{\epsilon}{\epsilon-1} \frac{\sum_{s=0}^{\infty} \theta^s E_t \left[\Lambda_{t,t+s} x^{-1}_{t+s} p^{\epsilon}_{t+s} y_{t+s} \right]}{\sum_{s=0}^{\infty} \theta^s E_t \left[\Lambda_{t,t+s} p^{\epsilon-1}_{t+s} y_{t+s} \right]} = \frac{\epsilon}{\epsilon-1} \frac{\sum_{s=0}^{\infty} (\beta\theta)^s E_t \left[u'(c_{t+s}) x^{-1}_{t+s} p^{\epsilon}_{t+s} y_{t+s} \right]}{\sum_{s=0}^{\infty} (\beta\theta)^s E_t \left[u'(c_{t+s}) p^{\epsilon-1}_{t+s} y_{t+s} \right]} \tag{59}$$

To numerically implement the optimal pricing equation in Dynare, summarize the equation above with two recursive formulations such that:

$$p_t^* = \frac{\epsilon}{\epsilon - 1}\frac{g_{1,t}}{g_{2,t}} \tag{60}$$

where

$$g_{1,t} \equiv u'(c_t)p_t^{\epsilon}y_t x_t^{-1} + \beta\theta E_t[g_{1,t+1}] = \frac{1}{c_t}p_t^{\epsilon}y_t x_t^{-1} + \beta\theta E_t[g_{1,t+1}] \tag{61}$$

$$g_{2,t} \equiv u'(c_t)p_t^{\epsilon-1}y_t + \beta\theta E_t[g_{2,t+1}] = \frac{1}{c_t}p_t^{\epsilon-1}y_t + \beta\theta E_t[g_{2,t+1}] \tag{62}$$

Let $f_{1,t} \equiv p_t^{-\epsilon}g_{1,t}$, then

$$f_{1,t} \equiv p_t^{-\epsilon}g_{1,t} = \frac{1}{c_t}y_t x_t^{-1} + \beta\theta E_t[\pi_{t+1}^{\epsilon}f_{1,t+1}] \tag{63}$$

Let $f_{2,t} \equiv p_t^{1-\epsilon}g_{2,t}$, then

$$f_{2,t} \equiv p_t^{1-\epsilon}g_{2,t} = \frac{1}{c_t}y_t + \beta\theta E_t[\pi_{t+1}^{\epsilon-1}f_{2,t+1}] \tag{64}$$

The optimal pricing equation $p_t^* = \frac{\epsilon}{\epsilon-1}\frac{g_{1,t}}{g_{2,t}}$ becomes:

$$p_t^* = \frac{\epsilon}{\epsilon - 1}\frac{f_{1,t}p_t^{\epsilon}}{f_{2,t}p_t^{\epsilon-1}} = \frac{\epsilon}{\epsilon - 1}\frac{f_{1,t}}{f_{2,t}}p_t \tag{65}$$

Divide both sides by p_{t-1} and let $\pi_t^* = \frac{p_t^*}{p_{t-1}}$ denote the gross reset price inflation rate to eliminate the price levels:

$$\pi_t^* = \frac{p_t^*}{p_{t-1}} = \frac{\epsilon}{\epsilon - 1}\frac{f_{1,t}}{f_{2,t}}\pi_t \tag{66}$$

B.2 Aggregate Price Evolution

Rearrange the aggregate price index (30):

$$p_t^{1-\epsilon} = \int_0^1 p_t(j)^{1-\epsilon}dj \tag{67}$$

Following Sims (2014),[12] the above integral can be broken up into two parts by ordering the retailers along the unit interval:

$$p_t^{1-\epsilon} = \int_0^{1-\theta} (p_t^*)^{1-\epsilon} dj + \int_{1-\theta}^1 p_{t-1}(j)^{1-\epsilon} dj = (1-\theta)(p_t^*)^{1-\epsilon} + \int_{1-\theta}^1 p_{t-1}(j)^{1-\epsilon} dj \tag{68}$$

Given the assumptions that the price-adjusting retailers in each period are randomly chosen and the number of retailers is large, the integral of individual prices over $[1-\theta, 1]$ of the unit interval is equal to a proportion θ of the integral over the entire unit interval, where θ is the length of the subset $[1-\theta, 1]$. That is,

$$\int_{1-\theta}^1 p_{t-1}(j)^{1-\epsilon} dj = \theta \int_0^1 p_{t-1}(j)^{1-\epsilon} dj = \theta p_{t-1}^{1-\epsilon} \tag{69}$$

Hence, the aggregate price level evolves according to (27):

$$p_t^{1-\epsilon} = (1-\theta)(p_t^*)^{1-\epsilon} + \theta p_{t-1}^{1-\epsilon} \tag{27}$$

To compute the model numerically, it is necessary to rewrite the price evolution in terms of the inflation rates because the price level may not be stationary. Eliminating the price levels in the equation above by dividing both sides by $p_{t-1}^{1-\epsilon}$:

$$\left(\frac{p_t}{p_{t-1}}\right)^{1-\epsilon} = \theta + (1-\theta)\left(\frac{p_t^*}{p_{t-1}}\right)^{1-\epsilon} \tag{70}$$

Let $\pi_t \equiv \frac{p_t}{p_{t-1}}$ and $\pi_t^* \equiv \frac{p_t^*}{p_{t-1}}$ denote the gross inflation rate and the gross reset price inflation rate respectively, then the equation above can be rewritten as:

$$\pi_t^{1-\epsilon} = \theta + (1-\theta)(\pi_t^*)^{1-\epsilon} \tag{71}$$

B.3 Price Dispersion

Use the Calvo assumption to break up the integral into two parts by ordering the retailers along the unit interval:

$$f_{3,t} \equiv \int_0^1 \left[\frac{p_t(j)}{p_t}\right]^{-\epsilon} dj = \int_0^{1-\theta} \left(\frac{p_t^*}{p_t}\right)^{-\epsilon} dj + \int_{1-\theta}^1 \left[\frac{p_{t-1}(j)}{p_t}\right]^{-\epsilon} dj \tag{72}$$

[12] https://www3.nd.edu/~esims1/new_keynesian_2014.pdf

Rearrange and simplify by using the definitions for π_t and π_t^*:

$$f_{3,t} = \int_0^{1-\theta} \left(\frac{p_t^*}{p_{t-1}} \frac{p_{t-1}}{p_t} \right)^{-\epsilon} dj + \int_{1-\theta}^{1} \left[\frac{p_{t-1}(j)}{p_{t-1}} \frac{p_{t-1}}{p_t} \right]^{-\epsilon} dj = (1-\theta)(\pi_t^*)^{-\epsilon}\pi_t^{\epsilon} + \pi_t^{\epsilon} \int_{1-\theta}^{1} \left[\frac{p_{t-1}(j)}{p_{t-1}} \right]^{-\epsilon} dj \tag{73}$$

Use the same method as in Appendix B.2 to simplify the last term in the equation above:

$$\int_{1-\theta}^{1} \left[\frac{p_{t-1}(j)}{p_{t-1}} \right]^{-\epsilon} dj = \theta \int_0^1 \left[\frac{p_{t-1}(j)}{p_{t-1}} \right]^{-\epsilon} dj = \theta f_{3,t-1} \tag{74}$$

Hence, the price dispersion $f_{3,t}$ can be written recursively:

$$f_{3,t} = (1-\theta)(\pi_t^*)^{-\epsilon}\pi_t^{\epsilon} + \pi_t^{\epsilon}\theta f_{3,t-1} \tag{75}$$

The index j has been eliminated in the above expression, so there is no need to keep track of the individual prices. Using (28), (72) and (75), the final consumption good output y_t is:

$$y_t = \frac{y_{w,t}}{f_{3,t}} = \frac{y_{w,t}}{(1-\theta)(\pi_t^*)^{-\epsilon}\pi_t^{\epsilon} + \pi_t^{\epsilon}\theta f_{3,t-1}} \tag{76}$$

The real profit Π_t^R made by the continuum of unit mass retailers is:

$$\Pi_t^R = \int_0^1 \left[\frac{p_t(j)}{p_t} y_t(j) - \frac{1}{x_t} y_t(j) \right] dj = \int_0^1 \frac{p_t(j)}{p_t} y_t(j) dj - \frac{1}{x_t} \int_0^1 y_t(j) dj \tag{77}$$

Use retailer $j's$ individual demand function $y_t(j) = \left[\frac{p_t(j)}{p_t} \right]^{-\epsilon} y_t$ (22), the wholesale good output expression $y_{w,t} = \int_0^1 y_t(j) dj$ (28), the aggregate price index $p_t = \left[\int_0^1 p_t(j)^{1-\epsilon} dj \right]^{\frac{1}{1-\epsilon}}$ (23), and (76) to get (29):

$$\Pi_t^R = \int_0^1 \frac{p_t(j)}{p_t} \left[\frac{p_t(j)}{p_t} \right]^{-\epsilon} y_t dj - \frac{y_{w,t}}{x_t} = y_t p_t^{\epsilon-1} \int_0^1 p_t(j)^{1-\epsilon} dj - \frac{y_{w,t}}{x_t} = y_t - \frac{y_{w,t}}{x_t} = \left(\frac{1}{f_{3,t}} - \frac{1}{x_t} \right) y_{w,t} \tag{29}$$

C Steady State Values

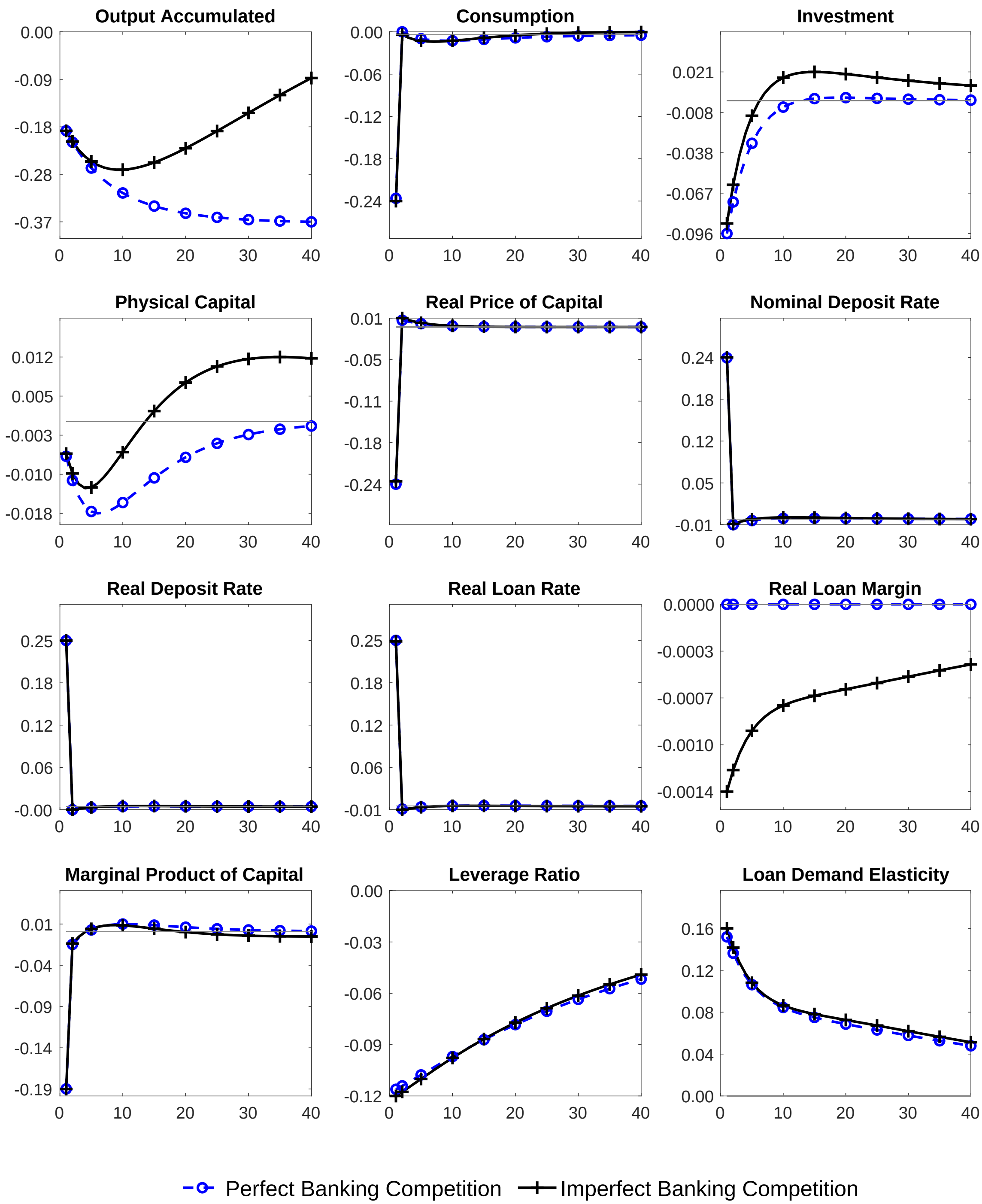
Table 2: Steady State Values under Baseline Calibration

	Perfect Competition	Imperfect Competition
Gross Inflation Rate π	1	1
Productivity z	1	1
Output y	0.983	0.880
Consumption c	0.647	0.607
Investment i	0.336	0.273
Physical Capital k	4.806	3.899
Real Price of Capital q	1	1
Bank Loan b	3.802	2.597
Labor l	0.283	0.273
Real Wage w	1.623	1.503
Gross Real Deposit Rate R_r	1.005	1.005
Gross Real Loan Rate R_{rb}	1.005	1.013
Firms' Total Net Worth n	1.004	1.302
Leverage Ratio $\frac{b}{qk}$	0.791	0.666
Marginal Product of Capital $\frac{\alpha_k y}{k}$	0.090	0.099
Capital Demand Elasticity PEK	23.921	21.857
Loan Demand Elasticity PED	30.240	32.815

Note: The table shows the steady state values of selected variables from two models with perfect banking competition and Cournot banking competition respectively. The steady state values for gross inflation rate and productivity are exogenously set to one. The steady state values of all other variables are determined in equilibrium, based on the parameter values in Table 1.

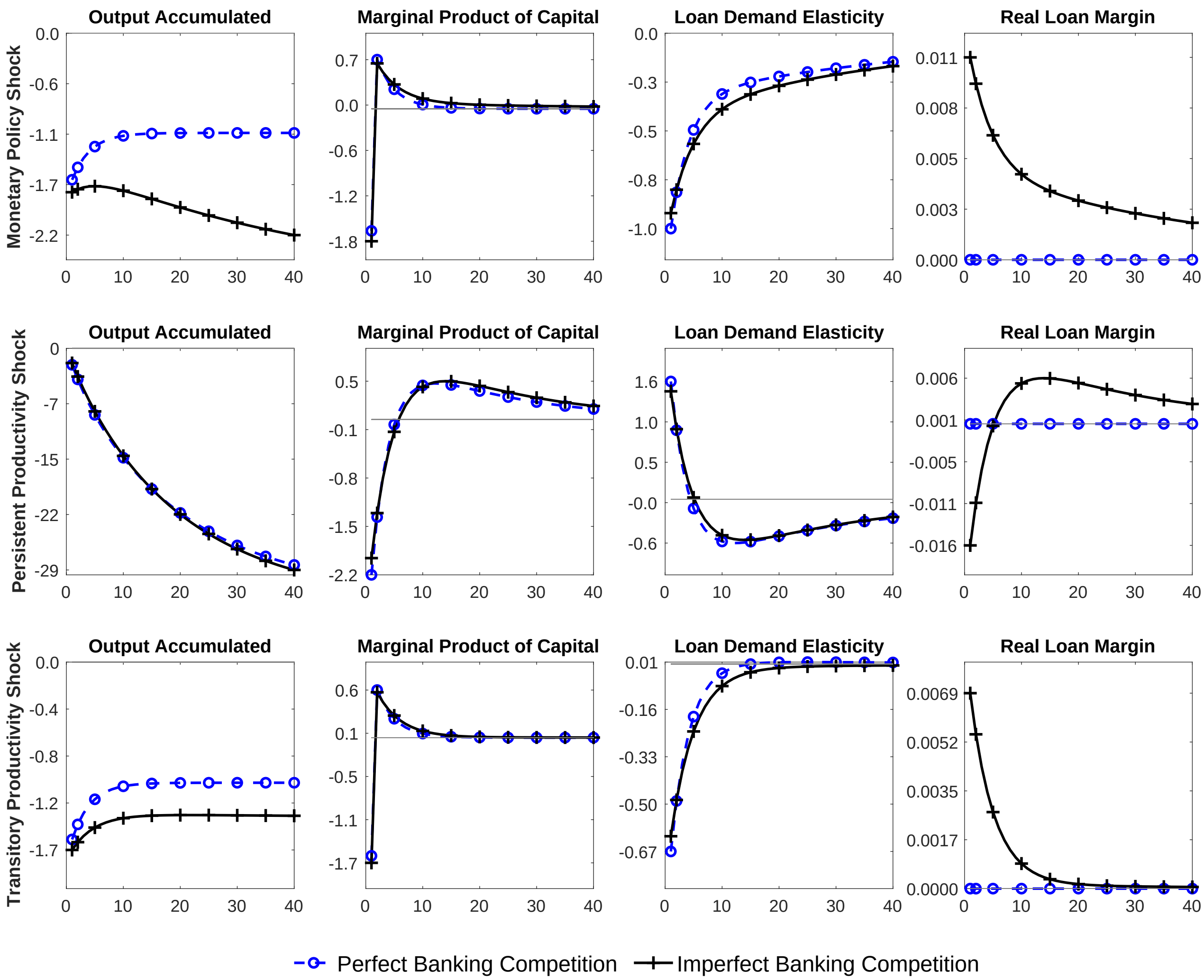
D Robustness Checks

Figure 7: Impulse Responses to a Negative Transitory Productivity Shock when $\chi = 2$



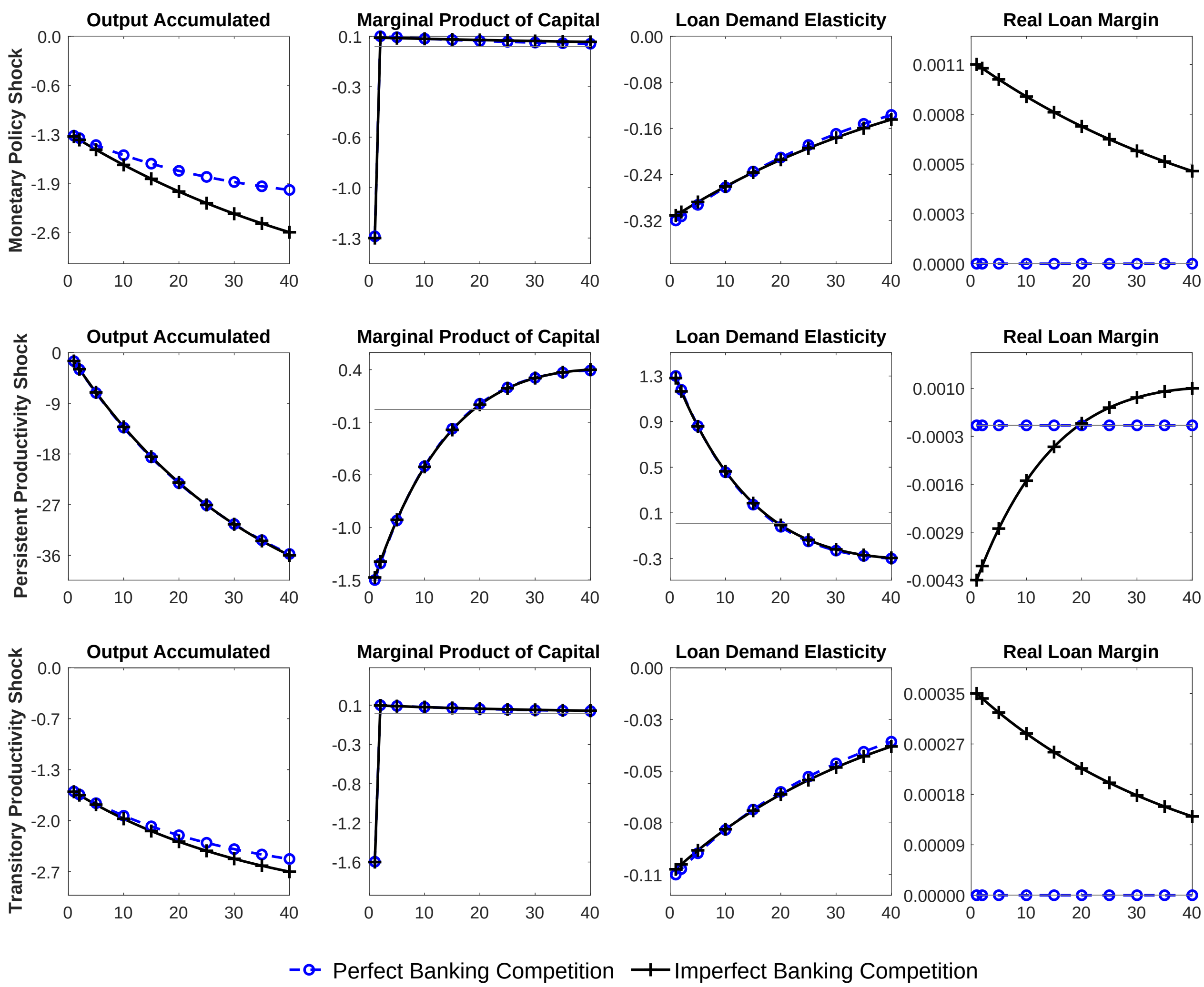
Note: Horizontal axis shows quarters after a one-standard-deviation negative productivity shock at the beginning of period 1. The persistence parameter ψ in the AR(1) process for productivity is set to zero, so the shock is fully transitory. Vertical axis shows the percentage deviation from the steady state for variables other than the interest rates and the loan margin, which are expressed in deviations from the steady state in percent points. Leverage ratio refers to the debt-to-asset ratio $\frac{b_t}{q_t k_t}$ and marginal product of capital is $\frac{\alpha_k y_t}{k_{t-1}}$.

Figure 8: Impulse Responses for Different Shocks when $\alpha_k = 0.25$ and $\alpha_l = 0.75$



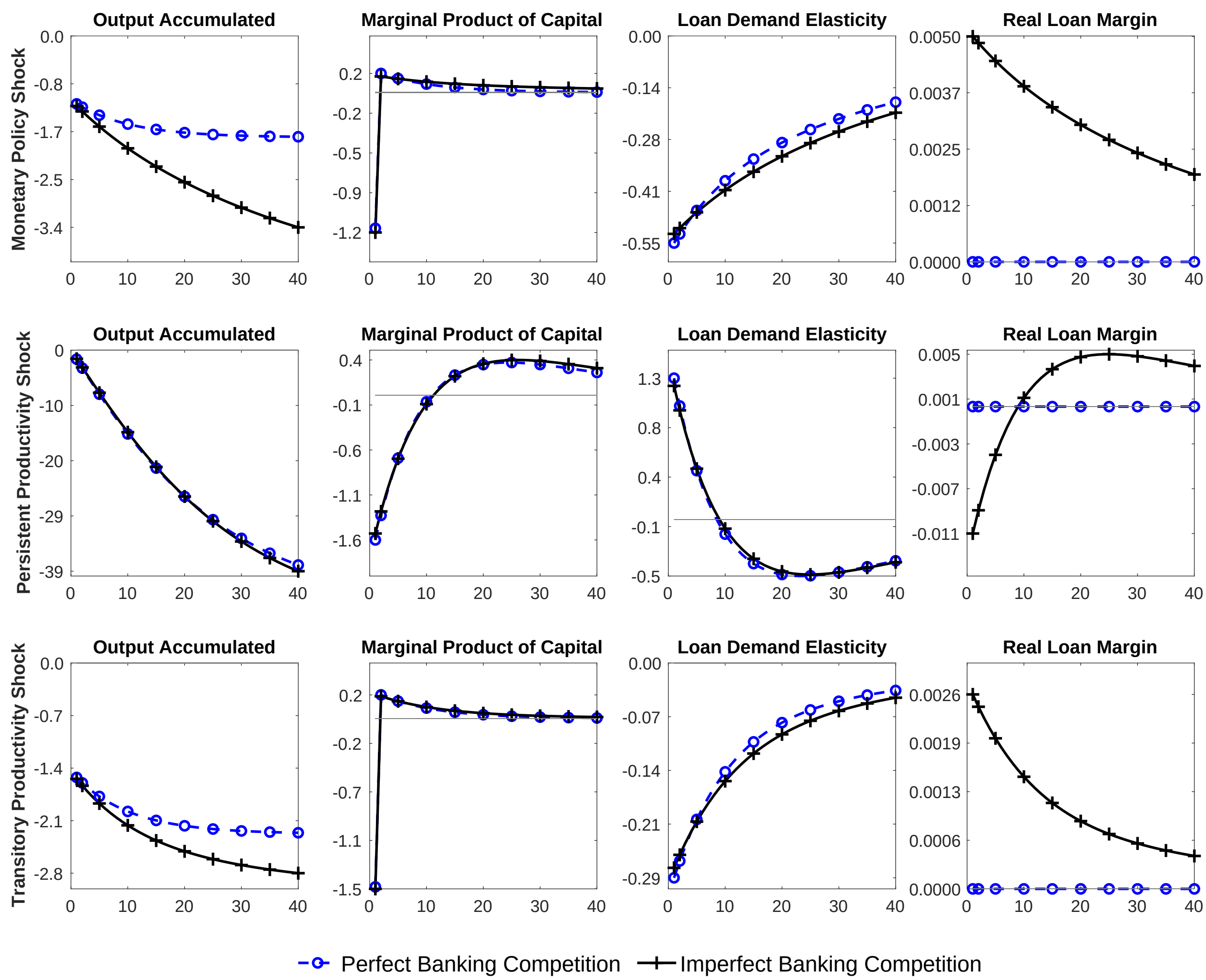
Note: Horizontal axis shows quarters after the shock that occurs at the beginning of period 1. Vertical axis shows the percentage deviation from the steady state for variables other than the loan margin, which is expressed in deviations from the steady state in percent points. Each row shows the impulse responses of four variables after a given type of shock: a 25 basis-point contractionary monetary policy shock, a one-standard-deviation persistent negative productivity shock ($\psi = 0.95$), and a one-standard-deviation transitory negative productivity shock ($\psi = 0$).

Figure 9: Impulse Responses for Different Shocks when $\delta = 0.025$



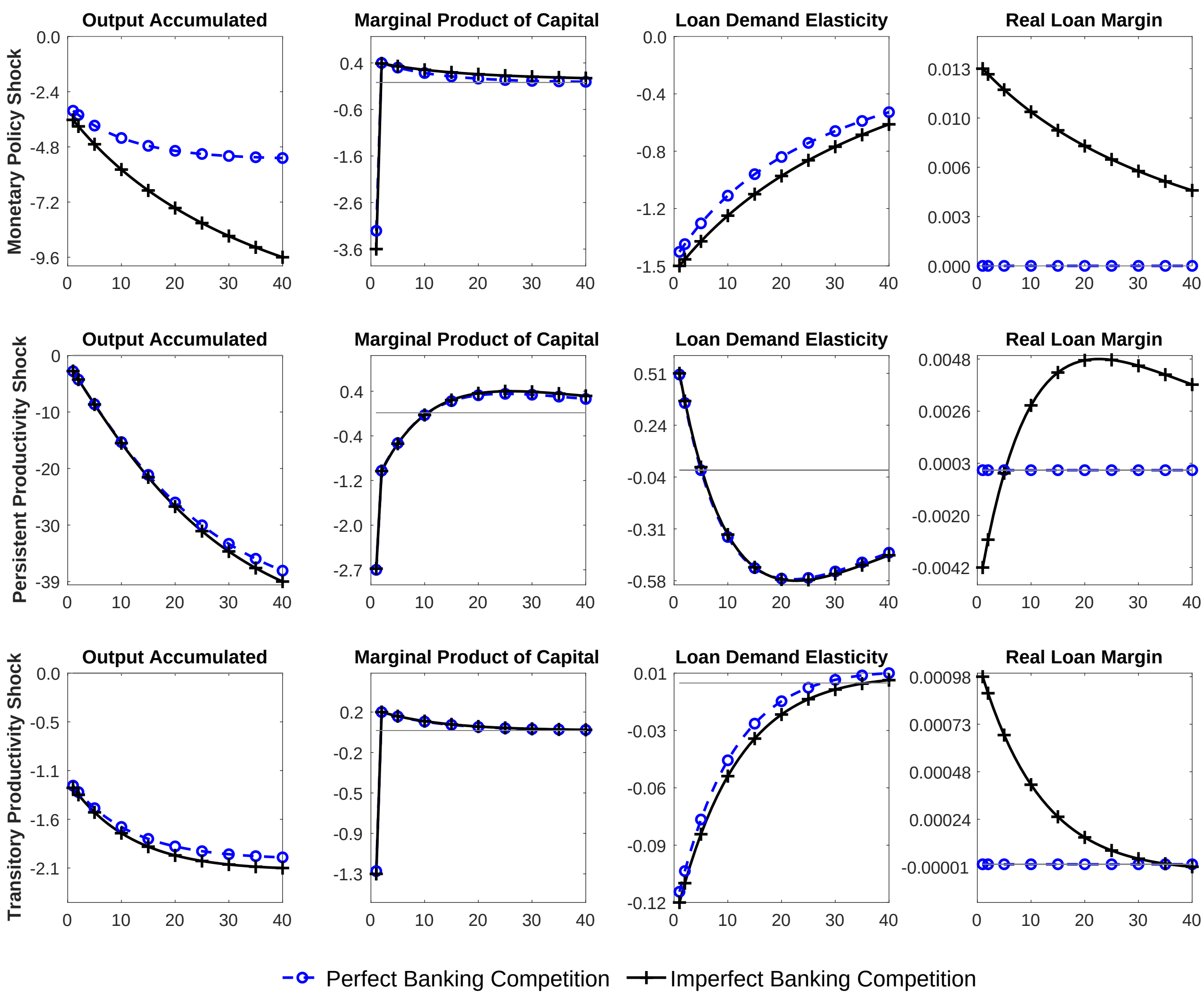
Note: Horizontal axis shows quarters after the shock that occurs at the beginning of period 1. Vertical axis shows the percentage deviation from the steady state for variables other than the loan margin, which is expressed in deviations from the steady state in percent points. Each row shows the impulse responses of four variables after a given type of shock: a 25 basis-point contractionary monetary policy shock, a one-standard-deviation persistent negative productivity shock ($\psi = 0.95$), and a one-standard-deviation transitory negative productivity shock ($\psi = 0$).

Figure 10: Impulse Responses for Different Shocks when $\omega = 0.0021$



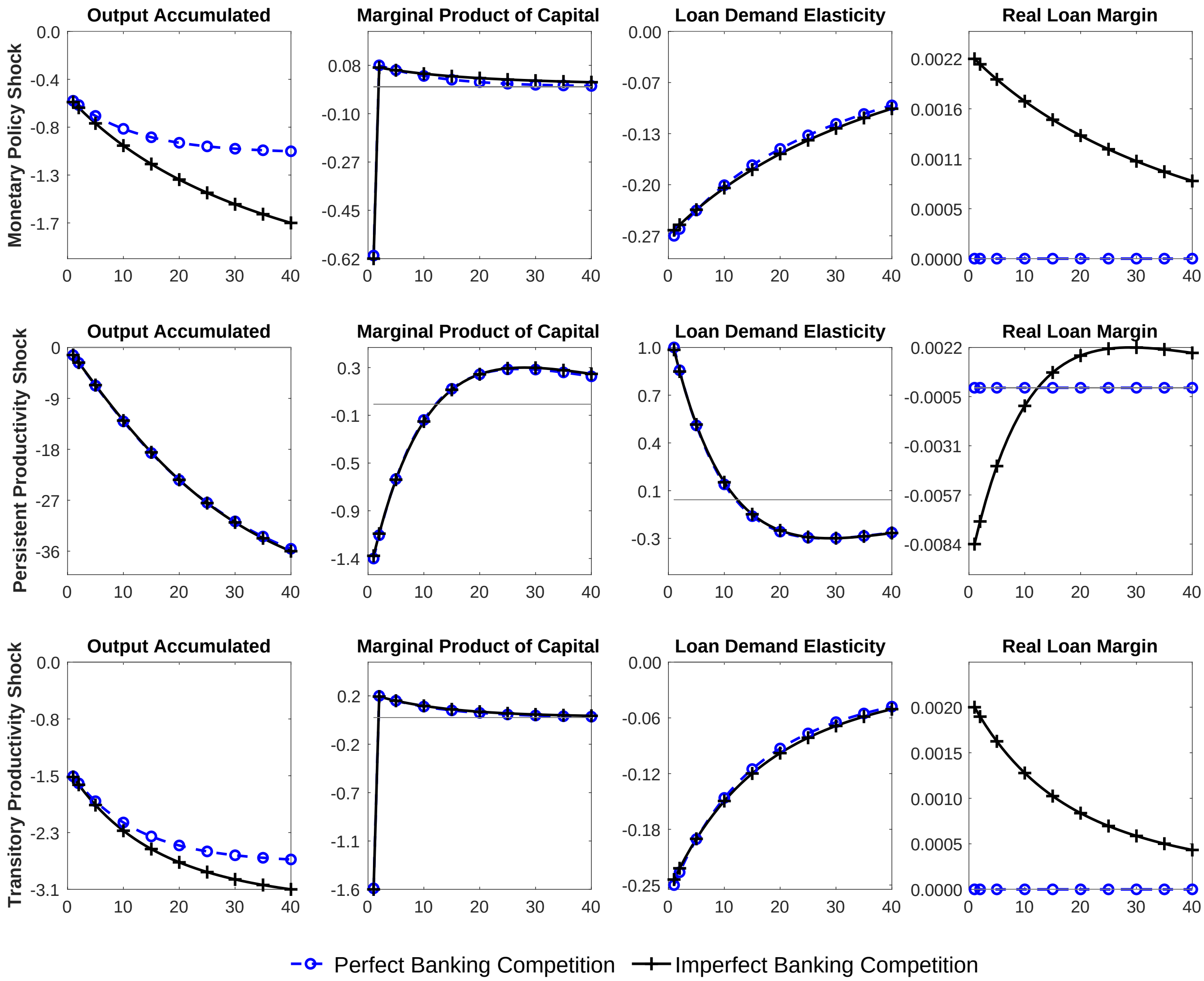
Note: Horizontal axis shows quarters after the shock that occurs at the beginning of period 1. Vertical axis shows the percentage deviation from the steady state for variables other than the loan margin, which is expressed in deviations from the steady state in percent points. Each row shows the impulse responses of four variables after a given type of shock: a 25 basis-point contractionary monetary policy shock, a one-standard-deviation persistent negative productivity shock ($\psi = 0.95$), and a one-standard-deviation transitory negative productivity shock ($\psi = 0$).

Figure 11: Impulse Responses for Different Shocks when $\rho_r = 0.7$



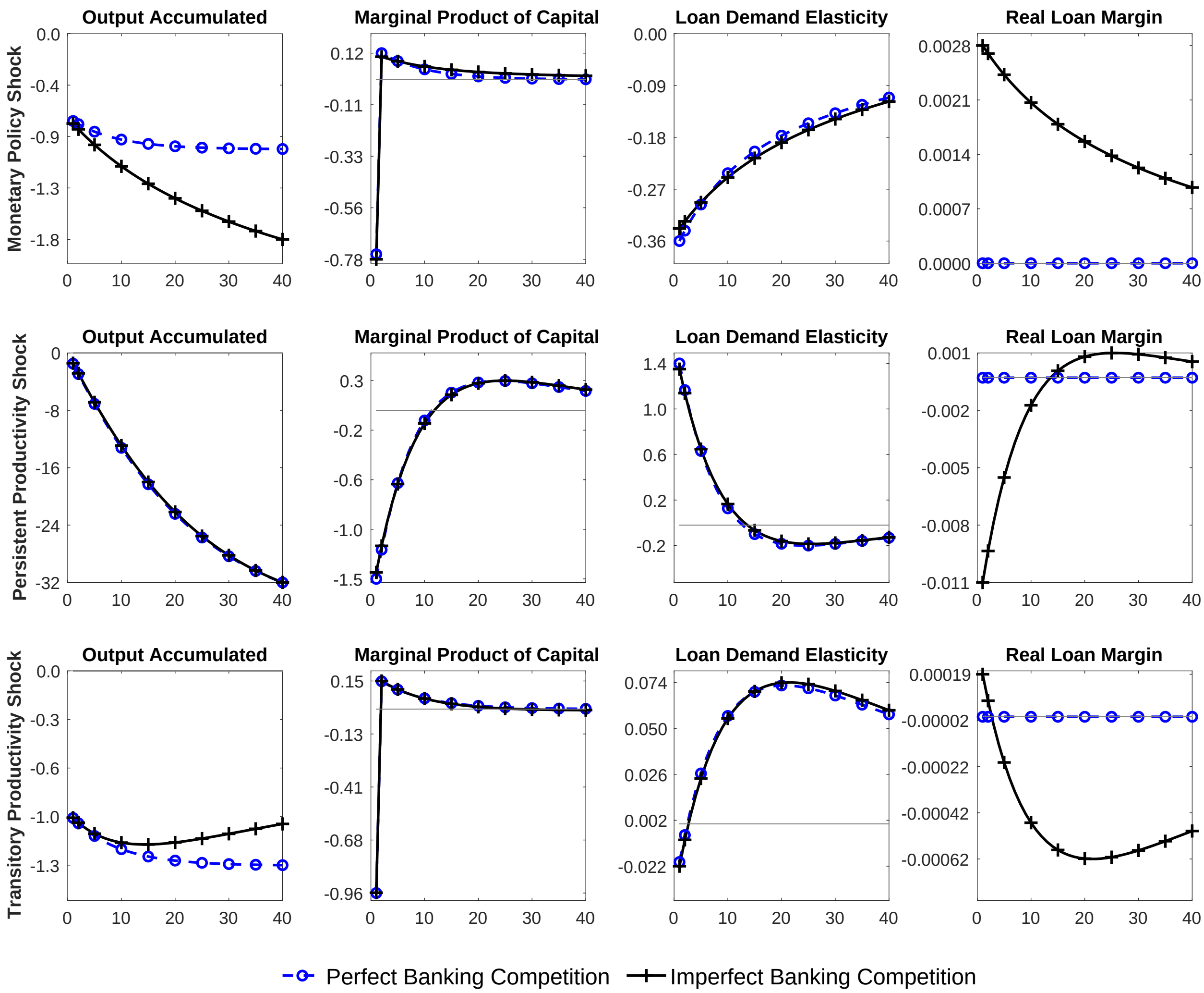
Note: Horizontal axis shows quarters after the shock that occurs at the beginning of period 1. Vertical axis shows the percentage deviation from the steady state for variables other than the loan margin, which is expressed in deviations from the steady state in percent points. Each row shows the impulse responses of four variables after a given type of shock: a 25 basis-point contractionary monetary policy shock, a one-standard-deviation persistent negative productivity shock ($\psi = 0.95$), and a one-standard-deviation transitory negative productivity shock ($\psi = 0$).

Figure 12: Impulse Responses for Different Shocks when $\kappa_\pi = 3$



Note: Horizontal axis shows quarters after the shock that occurs at the beginning of period 1. Vertical axis shows the percentage deviation from the steady state for variables other than the loan margin, which is expressed in deviations from the steady state in percent points. Each row shows the impulse responses of four variables after a given type of shock: a 25 basis-point contractionary monetary policy shock, a one-standard-deviation persistent negative productivity shock ($\psi = 0.95$), and a one-standard-deviation transitory negative productivity shock ($\psi = 0$).

Figure 13: Impulse Responses for Different Shocks when $\kappa_y = 0.125$



Note: Horizontal axis shows quarters after the shock that occurs at the beginning of period 1. Vertical axis shows the percentage deviation from the steady state for variables other than the loan margin, which is expressed in deviations from the steady state in percent points. Each row shows the impulse responses of four variables after a given type of shock: a 25 basis-point contractionary monetary policy shock, a one-standard-deviation persistent negative productivity shock ($\psi = 0.95$), and a one-standard-deviation transitory negative productivity shock ($\psi = 0$).

References

Agénor, Pierre-Richard, and Peter J. Montiel. 2015. *Development Macroeconomics.* Princeton University Press.

Andrés, Javier, and Oscar Arce. 2012. "Banking Competition, Housing Prices and Macroeconomic Stability." *Economic Journal*, 122(565): 1346–1372.

Beck, Thorsten, Andrea Colciago, and Damjan Pfajfar. 2014. "The Role of Financial Intermediaries in Monetary Policy Transmission." *Journal of Economic Dynamics and Control*, 43: 1–11.

Berg, Sigbjørn Atle, and Moshe Kim. 1998. "Banks as Multioutput Oligopolies: An Empirical Evaluation of the Retail and Corporate Banking Markets." *Journal of Money, Credit and Banking*, 30(2): 135–153.

Bernanke, Ben, Mark Gertler, and Simon Gilchrist. 1996. "The Financial Accelerator and the Flight to Quality." *Review of Economics and Statistics*, 78(1): 1–15.

Bernanke, Ben S, Mark Gertler, and Simon Gilchrist. 1999. "The Financial Accelerator in a Quantitative Business Cycle Framework." *Handbook of Macroeconomics*, 1: 1341–1393.

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

Calvo, Guillermo A. 1983. "Staggered Prices in a Utility-maximizing Framework." *Journal of Monetary Economics*, 12(3): 383–398.

Carlstrom, Charles T, and Timothy S Fuerst. 1997. "Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis." *American Economic Review*, 87(5): 893–910.

Christiano, Lawrence J, Martin Eichenbaum, and Charles L Evans. 2005. "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy." *Journal of Political Economy*, 113(1): 1–45.

Cuciniello, Vincenzo, and Federico Maria Signoretti. 2015. "Large Banks, Loan Rate Markup and Monetary Policy." *International Journal of Central Banking*, 11(3): 141–177.

De Bandt, Olivier, and E Philip Davis. 2000. "Competition, Contestability and Market Structure in European Banking Sectors on the Eve of EMU." *Journal of Banking & Finance*, 24(6): 1045–1066.

Dib, Ali. 2010. "Banks, Credit Market Frictions, and Business Cycles." Bank of Canada Working Paper, No.2010-24.

Dixit, Avinash K, and Joseph E Stiglitz. 1977. "Monopolistic Competition and Optimum Product Diversity." *American Economic Review*, 67(3): 297–308.

Ehrmann, Michael, Leonardo Gambacorta, Jorge Martínez-Pagés, Patrick Sevestre, and Andreas Worms. 2001. "Financial Systems and the Role of Banks in Monetary Policy Transmission in the Euro Area." ECB Working Paper, No.105.

Gerali, Andrea, Stefano Neri, Luca Sessa, and Federico M Signoretti. 2010. "Credit and Banking in a DSGE Model of the Euro Area." *Journal of Money, Credit and Banking*, 42(s1): 107–141.

Gertler, Mark, and Nobuhiro Kiyotaki. 2010. "Financial Intermediation and Credit Policy in Business Cycle Analysis." *Handbook of Monetary Economics*, 3(3): 547–599.

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

Gertler, Mark, Nobuhiro Kiyotaki, and Albert Queralto. 2012. "Financial Crises, Bank Risk Exposure and Government Financial Policy." *Journal of Monetary Economics*, 59(supplement): S17–S34.

Gilchrist, Simon, Alberto Ortiz, and Egon Zakrajsek. 2009. "Credit Risk and the Macroeconomy: Evidence from an Estimated DSGE Model." Unpublished Manuscript, Boston University.

Hafstead, Marc, and Josephine Smith. 2012. "Financial Shocks, Bank Intermediation, and Monetary Policy in a DSGE Model." Unpublished Manuscript.

Hülsewig, Oliver, Eric Mayer, and Timo Wollmershäuser. 2009. "Bank Behavior, Incomplete Interest Rate Pass-through, and the Cost Channel of Monetary Policy Transmission." *Economic Modelling*, 26(6): 1310–1327.

Iacoviello, Matteo. 2005. "House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle." *American Economic Review*, 95(3): 739–764.

Kalemli-Ozcan, Sebnem, Bent Sorensen, and Sevcan Yesiltas. 2012. "Leverage across Firms, Banks, and Countries." *Journal of International Economics*, 88(2): 284–298.

Kiyotaki, Nobuhiro, and John Moore. 1997. "Credit Cycles." *Journal of Political Economy*, 105(2): 211–248.

Mandelman, Federico S. 2010. "Business Cycles and Monetary Regimes in Emerging Economies: A Role for a Monopolistic Banking Sector." *Journal of International Economics*, 81(1): 122–138.

Mandelman, Federico S. 2011. "Business Cycles and the Role of Imperfect Competition in the Banking System." *International Finance*, 14(1): 103–133.

Oxenstierna, Gabriel C. 1999. "Testing for Market Power in the Swedish Banking Oligopoly." Stockholm University.

Rotemberg, Julio J. 1982. "Monopolistic Price Adjustment and Aggregate Output." *The Review of Economic Studies*, 49(4): 517–531.

Townsend, Robert M. 1979. "Optimal Contracts and Competitive Markets with Costly State Verification." *Journal of Economic Theory*, 21(2): 265–293.