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Financial Intermediation, Investment, and Monetary Policy

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Financial Intermediation, Investment, and Monetary Policy*

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Abstract

We develop a search-theoretic monetary general equilibrium model in which the effective lower bound (ELB) on nominal interest rates arises endogenously from the interaction between banks and credit-dependent firms. A wedge between deposit and lending rates, driven by the financial market microstructure and firm characteristics, limits credit expansion as policy rates decline. The ELB – a nominal rate below which monetary easing fails to stimulate output or investment – is higher when bank market power is greater or firms face tighter borrowing constraints, highlighting the role of financial conditions for monetary policy transmission. Our findings - theoretical and quantitative – underscore the importance of financial intermediaries in shaping the ELB and support a complementary role for macroprudential regulation and standard monetary policy tools.

JEL Classification: E22; E31; E41; E43; E52; G11; G21

Keywords: New Monetarism; Banks; Monetary Policy; Investment; Transmission Channels

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1 Introduction

The effective lower bound (ELB) on nominal interest rates has become central to modern macroeconomics, particularly after Japan's stagnation in the late 1990s and the global experience following the 2008 financial crisis (Eggertsson and Krugman, 2012; Krugman, 1998). Standard models treat the ELB as an exogenous constraint – typically at or near zero – below which conventional monetary policy loses traction, giving rise to liquidity traps (Eggertsson and Woodford, 2003). In this paper, we develop a model in which the ELB is *endogenous*: it arises from the interaction between the banking system and credit-dependent firms. Banks' market power in the credit market, along with their operating costs, generate a wedge between the deposit rates paid to households and the loan rates charged to firms. When policy rates fall below the endogenous ELB, banks withhold credit expansion as the rising value of household deposits fails to sustain the growing loan demand by firms. We show that greater bank market power and tighter firm-level financial constraints both raise the ELB, causing the economy to hit it at a higher nominal rate. These findings underscore that financial conditions – not just the level of nominal interest rates – are critical for the transmission of monetary policy (Caballero and Simsek, 2024; Kashyap and Stein, 2023).

The theoretical framework builds on the recent advances in monetary economics, surveyed in Lagos et al. (2017). Firms sell final goods produced using intermediate goods as factor inputs to households in exchange for liquid assets. Both capacities – factor inputs and liquid assets – are acquired ex ante, generating a problem with two-sided capacity constraints similar to Baughman and Rabinovich (2021). A coordination game determines equilibrium allocations, where the firm's capacity choice is the best response to the household's liquidity choice, and vice versa. We introduce banks operating on both sides of the market to assess the role of financial intermediaries in the transmission of monetary policy. They perform liquidity transformation, providing households with alternative media of exchange to fiat money, and intermediate funds to firms in need of a loan to fund factor inputs in line with Gu et al. (2013) and Altermatt (2022). Specifically, they attract liquid deposits from households in a Walrasian market and invest them in reserves and collateralized loans bilaterally bargained over with firms in an over-the-counter market. The latter establishes a positive pass-through from nominal interest rates to lending rates qualitatively similar to Rocheteau et al. (2018) and Jackson and Madison (2022), though the mechanism differs. A change in the nominal interest rate changes the household's purchasing power, thus affecting the firm's best-response capacity choice and, ceteris paribus, the lending rate. Market-clearing of loans and deposits is governed by an interbank market, where the spread between lending and deposit rates depends on the financial market microstructure (bank market power and operating costs) and firm characteristics (collateral constraints and payment technologies).

The model establishes a negative relationship between inflation and investment, a so-called reverse Mundell (1963) and Tobin (1965) effect (see Section 1.1 for details on the Mundell-Tobin effect). A reduction in inflation improves the purchasing power of households, causing firms to increase their investment in intermediate goods to satisfy the increased demand for final goods. The extent to which monetary policy easing improves equilibrium allocations depends on the firm's ability to expand investment, and thus the credit supply in the financial sector. Our results show that, contrary to the literature following the typical Lagos and Wright (2005) setup with one-sided capacity constraints, goods market allocations do not necessarily improve following a reduction in inflation, as firms cannot adjust their output on the spot. Instead, there emerges an endogenous ELB – a threshold nominal interest rate below which monetary policy has little to no effect on interest rates or output – as the rising value of household deposits fails to sustain the firms' accelerated loan demand.[1] Crucially, the level of the ELB depends on firm characteristics and the market microstructure of the financial sector.

We next evaluate the model's quantitative implications for the effectiveness of monetary policy. To do so, we calibrate its parameters to key real, monetary, and financial moments from the U.S. economy. In the benchmark calibration, the firms' collateral constraint does not bind: the financial sector passively adjusts to fundamentals, corresponding to "normal times". We then consider two alternative model specifications to assess how financial conditions influence monetary policy transmission. In the first, the firms' collateral constraint binds, limiting firms' access to credit and making the banking sector relevant for real economic activity (a regime we refer to as "credit rationing"). In the second, we further increase banks' bargaining power in the credit market, allowing banks to extract a larger share of the surplus and amplifying their influence on the real economy (thus, we dub this regime "credit rationing with high bank power").

Our numerical results illustrate how the three model variants respond to a decline in the nominal interest rate. To begin with, all versions exhibit positive interest rate pass-through: monetary easing lowers the interbank rate, which in turn reduces both lending and deposit rates, as these are tied to interbank market conditions. The mechanism operates through households' increased purchasing power – driven by lower nominal rates – which raises the value of deposits. This, in turn, reduces the interbank rate, transmitting the policy rate cut across the financial system. Next, we show that the efficacy of monetary policy depends on the level of the nominal

[1] As detailed in Section 4, this ELB is neither zero— all rates remain strictly positive in every numerical experiment— nor the result of the Friedman rule, since output never attains its social optimum.

interest rate. Above the ELB, output rises in response to monetary easing in all model versions. As interest rates fall, banks expand credit to firms, enabling higher investment and production to meet stronger household purchasing power in the product market. Thus, each version of the model generates a reverse Mundell-Tobin effect, whereby lower nominal interest rates stimulate real activity. However, below the ELB, both interest rates and output become largely unresponsive; that is, conventional monetary policy loses traction. Importantly, the level of the ELB depends on financial sector characteristics. It is higher in the model specifications with credit rationing and elevated bank market power. In these settings, fewer loans are issued and at higher rates, hence monetary easing leads to a weaker credit response. As a result, monetary policy becomes ineffective at a higher nominal rate than in the benchmark case.

In sum, our analysis delivers a crucial policy lesson: the effectiveness of conventional monetary policy critically hinges on financial conditions – most notably, the market power of financial intermediaries. When credit is constrained and intermediaries wield substantial market power to extract surplus from the real economy, traditional monetary policy loses potency. While monetary easing may boost liquidity, its transmission falters as the financial sector fails to channel additional credit to firms. These results carry two major implications. First, they provide a theoretical foundation for non-standard monetary policy tools – such as quantitative easing and forward guidance – that central banks have deployed since the 2007–2009 financial crisis. Second, they identify the financial sector as a key bottleneck in monetary transmission. This reframes the relationship between conventional monetary policy and macroprudential regulation: rather than substitutes, they are complementary. By ensuring the stability and proper functioning of financial intermediaries, monetary authorities – acting as lenders of last resort – secure the effectiveness of conventional policy tools.

The rest of the paper is organized as follows. Section 1.1 discusses the related literature and presents empirical evidence to motivate and support the implications of our model. Section 2 presents the model with Section 2.1 outlining the environment, Section 2.2 characterizing the social optimum, and Sections 2.3-2.5 determining the portfolio choices and the terms of trade in the goods market and the banking sector. The monetary equilibrium is presented in Section 3, characterizing the households' and the firms' best response functions, and discussing the equilibrium allocations. Next, Section 4 presents the calibration strategy and the numerical results of various comparative statics exercises. Lastly, Section 5 concludes.

1.1 Related Literature and Empirical Motivation

Interest Rates and Real Investment. To begin with, our model builds on the literature studying the relationship between inflation and investment pioneered by Mundell (1963) and Tobin (1965). They characterize a positive relationship between inflation and capital accumulation – the so-called 'Mundell-Tobin effect' – if fiat money and capital are substitutes, revisited by Lagos and Rocheteau (2008) and Altermatt and Wipf (2024). A reverse Mundell-Tobin effect (a negative relationship between inflation and investment) was established by Aruoba et al. (2011), when fiat money is needed to purchase the goods produced with capital, and by Wright et al. (2018, 2020), when fiat money is needed to purchase capital as a productive input. Our paper extends this literature – aptly summarized in Gomis-Porqueras et al. (2020) – in two dimensions. First, in our model, capital accumulation is not an independent choice variable of firms but follows a coordination game similar to Baughman and Rabinovich (2021). Secondly, capital is neither a substitute for nor is it accumulated with fiat money, but instead its accumulation is financed with bank loans. More substantively, the choice of capital is a best response to the liquidity holdings of consumers purchasing the goods produced using that capital as a factor input. This also yields a reverse Mundell-Tobin effect similar to Wright et al. (2018, 2020) but the transmission channel is different and works through financial intermediaries. Moreover, this transmission mechanism leads to an important result of our paper: the strength of the reverse Mundell-Tobin effect depends on the terms of trade in the banking sector.

The empirical evidence regarding the Mundell-Tobin effect is mixed. On the one hand, Ahmed and Rogers (2000) and Rapach and Wohar (2005) provide evidence in favor of a positive Mundell-Tobin effect in low-frequency data. On the other hand, looking at higher frequencies, Feldstein (1982), Barro (1995), and Byrne and Davis (2004) find evidence in support of the reverse Mundell-Tobin effect. In Figure 1, we plot the time series of real investment as fraction of GDP together with the effective Federal Funds rate (the nominal interest rate and the inflation rate move together in our model through the Fisher equation). We also find that while the correlation was strongly positive until the late 1980's, it has become much more spurious since then. While there are several explanations for the weakening of this relationship (see, e.g., the important work of Mian et al. 2021), it is consistent with the increased importance of financial intermediation for the transmission of monetary policy, which is our main focus.

Monetary Policy and Bank Intermediation. To assess the effects of financial intermedia-

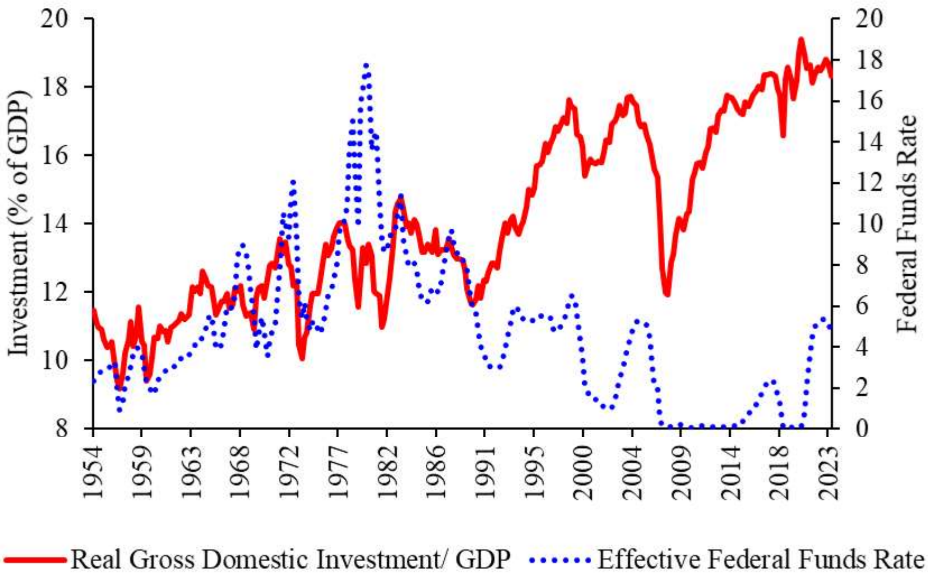


Figure 1: Real gross private domestic investment as a fraction of GDP (left axis) and effective federal funds rate (right axis) in the United States. Source: FRED.

tion on the transmission channel of monetary policy, the framework draws from the vast literature on banking pioneered by Diamond and Dybvig (1983), Boyd and Prescott (1986), Allen and Gale (1998), and Holmström and Tirole (1997, 1998). Incorporating the recent contributions in monetary theory, our model builds on Berentsen et al. (2007) and Williamson (2012), though the demand for banking services exists for different reasons.[2] In these studies, financial intermediation serves as an insurance against liquidity shocks – an idea closely related to asset reallocation in financial markets (see e.g. Berentsen et al. (2014) and Geromichalos and Herrenbrueck (2016)). In this paper, though, there exists no consumption uncertainty and banks perform liquidity transformation by issuing liquid liabilities, as in Gu et al. (2013) and Altermatt (2022). We deviate from these two studies and follow Rocheteau et al. (2018) modeling the lending sector as over-the-counter and giving market power to banks in the credit market.[3] While almost all of those studies focus exclusively on lending, we establish an explicit transmission channel from lending rates to deposit rates, determined competitively in a Walrasian market.[4]

Motivated by these theoretical considerations, Figure 2 presents supportive empirical evidence on the comovement of different interest rates in the economy. We focus on the rates through which

[2]New Keynesian applications of financial intermediation are provided by e.g. Bernanke et al. (1999) (costly state verification), Cúrdia and Woodford (2009) (leverage costs), and Gertler and Karadi (2011) (asset diversion).

[3]This framework has been extended to include entrepreneurs and home equity loans by Jackson and Madison (2022), and lending relationships by Bethune et al. (2022). Buera and Nicolini (2020) study credit crunch equilibria.

[4]For a study on the transmission channel of monetary policy to deposit rates exclusively see Drechsler et al. (2017) and Choi and Rocheteau (2023).

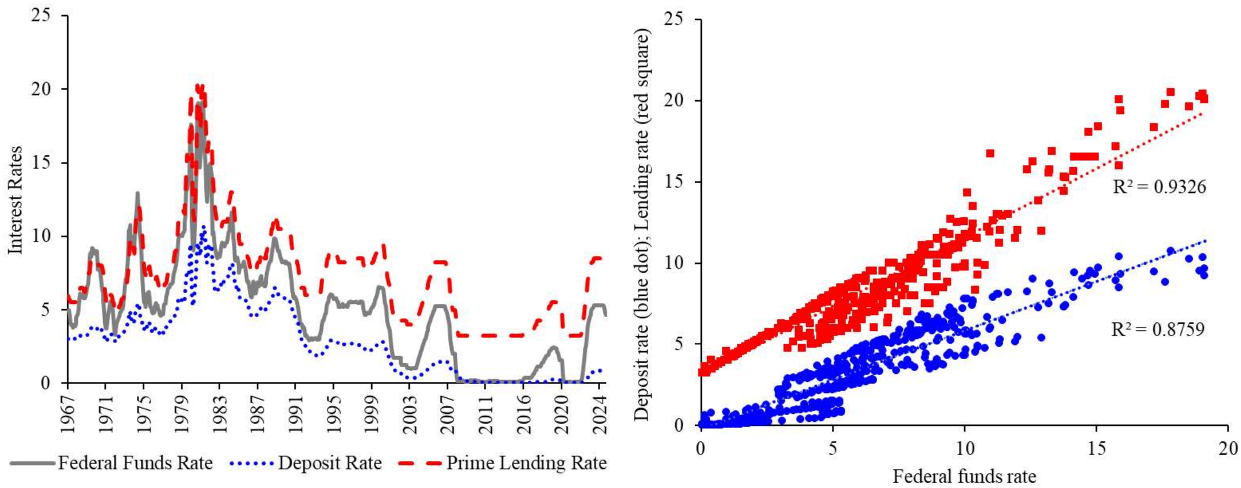


Figure 2: Interest rate pass-through in the United States. Source: FRED and Center for Financial Stability.

our model's theoretical mechanisms operate: the lending rate commercial banks charge firms in the credit market and the deposit rate banks pay depositors. The right panel presents the correlation coefficient between each rate and the federal funds rate. Both correlations are large, supporting the conclusion that banks adjust their rates to monetary policy movements, a central result of our theoretical model. Re-illustrating the co-movement, the left panel further shows that there exists a positive interest rate channel, indicating that banks extract a positive surplus in the lending sector consistent with the bargaining game in our model.

Bank Bargaining Power in the Credit Market. Lastly, our paper contributes to the broader literature on the macroeconomic implications of bank lending/ credit conditions for real allocations. Prominent examples include Bernanke (1983), Kashyap and Stein (2000), Diamond and Rajan (2006), Mian et al. (2020), and Bianchi and Bigio (2022). In the New Monetarist literature, there are several works studying the connection between interest rates and labor market outcomes (Bethune and Rocheteau, 2023; Gabrovski et al., 2025*b*; Lahcen et al., 2022) following the seminar work of Berentsen et al. (2011). Our paper is closer to those incorporating capital as a productive input- such as Gomis-Porqueras et al. (2020) and Gu et al. (2023)- as well as those modeling banks having market power- such as Dong et al. (2021), Chiu et al. (2023), Choi and Rocheteau (2023), and Head et al. (2025).

Our main contribution to this line of work is to incorporate the bargaining power of commercial banks in our model and study its implications for the transmission of monetary policy. Figure 3 presents the evolution of the total number of commercial banks in the US using data from the

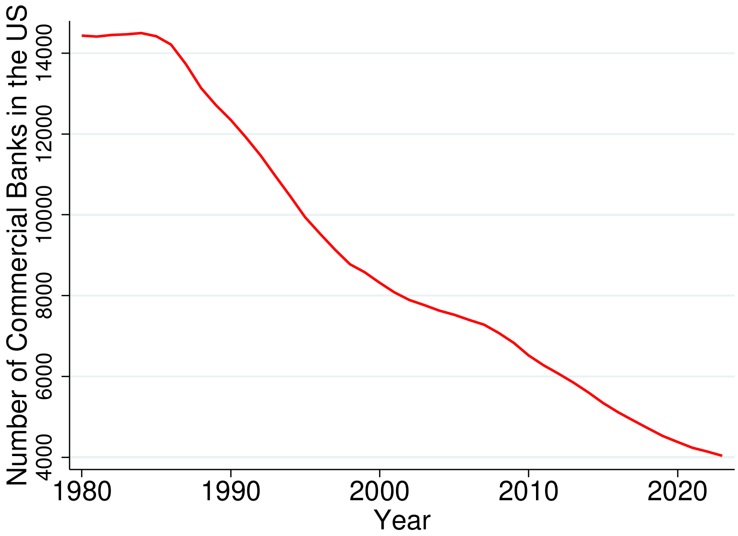


Figure 3: Total number of commercial banks in the United States. Source: FDIC.

Federal Deposit Insurance Corporation. The decline is striking: there were 14,210 commercial banks in 1986, while there are only 4,036 in 2023. This strong decline points to an increase in the bargaining power of banks in the US credit market.[5] Finally, Table 1 presents evidence from the Small Business Credit Survey for 2017 showing that a large number of firms that apply for bank lending receive only a fraction of the amount they applied for. Since bank loans are largely collateralized, this intensive margin points to haircuts, accounted for with Kiyotaki and Moore (1997) pledgeability parameters in our model.

Loan application outcomes	Fraction of Firms
All (100%)	46%
Most ($> 50\%$)	12%
Some ($< 50\%$)	20%
None (0%)	22%

Table 1: Total funding received by US firms in 2017. Source: Small Business Administration. 'All' corresponds to the fraction of firms that received 100% of the loan they applied for, 'Most' to the fraction that received over 50%, 'Some' to the fraction that received less than 50% (but received some funding), and 'None' to the fraction of firms that received zero funding.

[5]To further support this motivational fact, the literature has provided strong empirical evidence regarding the existence of market power in the banking sector; see Scharfstein and Sunderam (2016) and Drechsler et al. (2017).

2 Model

2.1 Environment

Time is discrete, starts at $t = 0$, and continues forever. Each period is divided into three stages, as visualized in Figure 4. In stage 1, two markets open simultaneously: a competitive capital market and a banking sector, subdivided into an over-the-counter (OTC) loan market and a competitive deposit market. In stage 2, using the capital acquired in stage 1 as factor input, a final good is produced and exchanged for a medium of exchange in a decentralized market. Lastly, in stage 3, agents produce and consume a numéraire good, settle outstanding loan obligations, and reallocate their portfolios in a competitive Arrow-Debreu market. The discount factor across periods is $\beta = (1 + r)^{-1} \in (0, 1)$ with $r > 0$ denoting the time rate of preference.

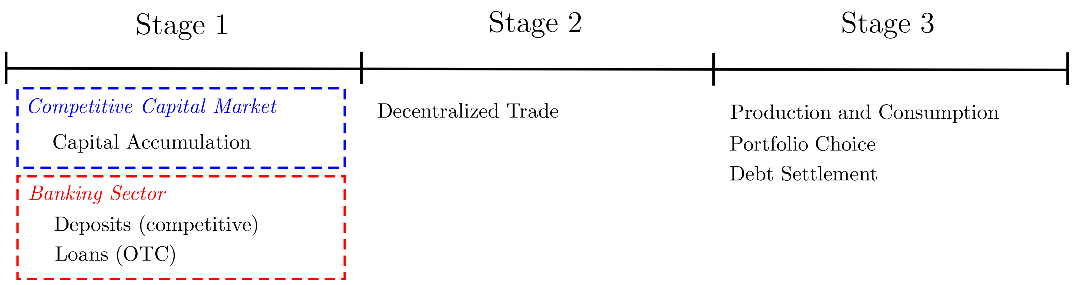


Figure 4: Timing of events

There are four types of agents, $\{h, f, b, s\}$ – households, firms, banks, and capital suppliers, each a measure one – and three types of goods, $\{k, q, x\}$ – capital (factor input), a final good, and a numéraire good. While households, banks, and capital suppliers are infinitely lived, firms are short-lived and exist for one period.[6] Capital, k, produced on the spot by capital suppliers in stage 1 and sold at a competitive price $\phi_k = 1$, is used by firms as the sole input to produce $q \leq k$ units of the final good in stage 2 at a cost $c(q)$, where $c'(q) > 0$, $c''(q) > 0$, $c'(0) = 0$, $c'(\infty) = \infty$, and $c(0) = 0$.[7] Households consume the produced final good, where consumption yields the utility $u(q)$ with $u'(q) > 0 > u''(q)$, $u'(0) = \infty$, $u'(\infty) = 0$, and $u(0) = 0$. Utility over the numéraire good in stage 3 is linear, $U(x) = x$, where $x > 0$ can be interpreted as consumption and $x < 0$ as production. While households and firms can produce the numéraire good in stage 3 (to accumulate liquid assets and settle loan obligations), for banks and capital suppliers $x \geq 0$ holds. Unused capital can be stored across periods. The final good and the numéraire good, in

[6] This allows for focusing on static rather than dynamic debt contracts between firms and banks. Furthermore, firms have no demand for fiat money in stage 3, reducing the money demand to households exclusively.

[7] Capital k can be interpreted as a proxy for a variety of factor inputs purchased/ hired at a competitive price and converted into a final good q at a cost $c(q)$.

turn, fully depreciate at the end of stages 2 and 3, respectively, and hence there are no gains from storage.

There is neither a record-keeping technology in the competitive capital market in stage 1 nor in the decentralized goods market in stage 2, and households and firms cannot commit to future actions, thus necessitating a medium of exchange for gains from trade to be realized. The available media of exchange are fiat money, nominal bank deposits, and nominal bank loans (tradeable IOUs). Since firms are short-lived (exist for one period), they have no funds (fiat money and bank deposits) of their own, and thus rely on external financing (bank loans) to purchase capital in stage 1. The terms of the loan contract (l, i_l) – loan size $l \in \mathbb{R}_+$ and lending rate $i_l \in \mathbb{R}_+$ – are bargained over bilaterally and matches are dissolved at the end of stage 3 after loan obligations are settled. Given the firm's inability to commit to future actions, bank loans must be collateralized (using claims on their future surplus) to ensure incentive-compatibility. Banks, in turn, are endowed with commitment power and can thus finance loans by issuing inside money (tradeable IOUs). Furthermore, they are not anonymous in stage 3, allowing depositors to collect their claims. To acquire the produced final good in the decentralized market in stage 2, households compensate firms with fiat money and bank deposits, where the terms of trade – the quantity of final goods the firm produces for the household and the liquidity the household transfers to the firm – are determined via bilateral bargaining.[8] Given the two-sided capacity constraints, the household's transfer cannot exceed its liquidity holdings and the firm's output cannot exceed its capacity. There are two types of firms denoted by the subscript $j \in \{O, I\}$: A fraction $\eta_O \in (0, 1)$ of *outside* firms only accepting fiat (outside) money in stage 2, and a fraction $\eta_I \equiv 1 - \eta_O$ of *inside* firms accepting both fiat money and bank deposits (inside money). In stage 3, households know with certainty which firm type they meet in the subsequent period and thus choose their portfolios accordingly.[9] Deposits are nominal claims priced competitively and banks govern the supply in stage 1 at the market-clearing deposit rate $i_d \in \mathbb{R}_+$, paid to the depositor in fiat money in stage 3. To finance the interest on deposits, banks can invest by issuing bank loans to firms.

The aggregate stock of fiat money is governed by a monetary authority according to the law of motion $M' = T + M$, where M and M' denote the stock of money today and tomorrow, respectively. Expansion and contraction are conducted through lump-sum transfers, $T \equiv \tau M$, in stage 3. Focusing on symmetric and stationary equilibria, it holds that $M'/M = \phi/\phi' = \gamma_m$, where

[8] For firms to be able to pledge collateral (future surplus) when obtaining a bank loan in stage 1, they need to extract some surplus in the goods market in stage 2. Bargaining provides a natural pricing mechanism to achieve that.

[9] In other words, there are no precautionary motives when households choose their portfolios, and hence banks have no insurance role in this economy. This formalization is in line with Altermatt (2022), guaranteeing a demand for fiat money if $i_d > 0$. Empirically, an η_I close to one but strictly smaller than one is realistic, i.e., very few meetings are cash-only. Cash-only firms can be interpreted as vendors for whom it is infinitely costly to acquire the technology to verify debit cards.

ϕ denotes today's price of fiat money denominated in the numéraire good, ϕ' tomorrow's price of fiat money, and γ_m the growth rate of the fiat money supply.

2.2 Social Optimum

Before proceeding to the monetary equilibrium, let us characterize the social optimum. A social planner maximizes the households' lifetime utility subject to the capacity constraint $q_{j,t} \leq k_{j,t}$ solving:

$$\max_{k_{j,t}, q_{j,t} \in [0, k_{j,t}]} \sum_{t=0}^{\infty} \beta^t \Big[\sum_{j=O,I} \eta_j \left[-k_{j,t} + u(q_{j,t}) - c(q_{j,t}) + (k_{j,t} - q_{j,t}) \right] \Big].$$

The first term represents the cost of acquiring the capacity $k_{t,j}$ in stage 1, where the second and the third term represent the value of exchanging $q_{j,t}$ in stage 2 and consuming the unsold inventory $k_{j,t} - q_{j,t}$ in stage 3. Assuming a stationary equilibrium, i.e., $k_{j,t} = k_j$ and $q_{j,t} = q_j$, the socially-optimal allocation (k_j^*, q_j^*) solves:

$$u'(q_j^*) - c'(q_j^*) - 1 = 0,$$

i.e., the social planner chooses (k_j^*, q_j^*) independent of the firm's capacity constraint.

2.3 Stage 3: Household Portfolio Choices

We solve the model recursively starting with the households' portfolio choice in stage 3. As is well established in models with quasi-linear preferences – see e.g. Lagos and Wright (2005) – the portfolio choice is independent of current wealth and all households of the same type enter stage 1 with the same portfolio. For brevity, the value functions are delegated to Appendix A.

Starting with a household trading with an outside firm, the household chooses the next period's portfolio of fiat money and bank deposits, (m_O', d_O'), solving:

$$\max_{m_O', d_O'} \quad - \quad (\phi/\beta - \phi')m_O' - (\phi/\beta - \phi'(1 + i_d'))d_O' + \Delta_h(m_O', k_O'), \tag{1}$$

where the first two terms represent the household's cost of acquiring m_O' and d_O'. The last term, $\Delta_h(m_O, k_O)$, denotes the household's stage 2 surplus as a function of the household's liquidity m_O (fiat money) and the firm's production capacity, k_O, determined via bilateral bargaining in Section 2.4. It is evident from (1) that bank deposits are only held if the interest rate at least compensates the household for inflation and discounting, e.g. $1 + i_d \geq \gamma/\beta$, where i satisfying $1 + i = \gamma/\beta$ is henceforward defined as the Fisher rate.[10] Fiat money, on the other hand, is held even if $1 < \gamma/\beta$ as an additional unit allows the household to increase its surplus in stage 2. The demand for fiat money is given by the first-order condition:

$$\phi = \beta\phi' + \beta\Delta_{h,m'_O}, \tag{2}$$

where Δ_{h,m'_O} denotes the household's marginal stage 2 surplus with respect to m'_O.

Let us now consider the portfolio choice of a household meeting a firm accepting fiat money and bank deposits in stage 2 (inside firm). The household's stage 3 problem solves:

$$\max_{m'_I, d'_I} \quad - \quad (\phi/\beta - \phi')m'_I - (\phi/\beta - \phi'(1 + i'_d))d'_I + \Delta_h(m'_I, d'_I, k'_I), \tag{3}$$

with $\Delta_h(m'_I, d'_I, k'_I)$ denoting the household's stage 2 surplus in a meeting with an inside firm, i.e., a firm accepting both fiat money and deposits. The deposit demand is given by the first-order condition:

$$\phi = \beta\phi'(1 + i'_d) + \beta\Delta_{h,d'_1}.$$

If $i'_d > 0$, then deposits dominate fiat money and thus (inside) households will not accumulate fiat money in stage 3. Indifference occurs for $i'_d = 0$. Since the real value of the household's liquid assets is the same for $i_d = 0$, i.e., $(m_I, d_I) = (m_I, 0) = (0, d_I)$, we assume going forward that households have a weak preference for deposits, and thus leave stage 3 with $(0, d_I)$ if $i_d \geq 0$. Lastly, if $i'_d < 0$, then fiat money dominates deposits and the money demand of inside and outside households is equivalent, i.e., $m'_I = m'_O$ satisfying (2). This case, however, cannot be an equilibrium outcome as shown in Section 2.5.

2.4 Stage 2: Goods Market

Outside (inside) firms and households, denoted by the subscript $j \in \{O, I\}$, enter stage 2 with capital inputs k_O (k_I) and liquidity m_O (m_I, d_I), respectively. They meet bilaterally and exchange final goods $q_j \in [0, k_j]$ for fiat money and bank deposits, $\hat{m}_j \in [0, m_j]$ and $\hat{d}_j \in [0, d_j]$ – a problem with two-sided capacity constraints similar to Baughman and Rabinovich (2021).[11] The terms of

[10]Using $\beta = (1 + r)^{-1}$ with r being the natural interest rate, the Fisher rate is defined as the interest rate at which the Fisher (1930) equation holds with equality, i.e., the rate at which households are exactly compensated for inflation and discounting, $1 + i = \gamma(1 + r)$. See Altermatt (2022) and Geromichalos and Herrenbrueck (2022) for a detailed discussion.

[11]Imposing trade with two-sided capacity constraints challenges two assumptions commonly made in the literature: (i) deep pockets, i.e., no liquidity constraints, and (ii) on the spot production, i.e., no capacity constraint. See Dutu and Julien (2008), Masters (2013), and Anbarci et al. (2019) for related papers studying decentralized retail markets with production in advance.

trade are determined using the proportional bargaining solution by Kalai (1977).[12] Let $\theta \in (0,1)$ denote the household's bargaining power and $1-\theta$ the firm's bargaining power. Given the linearity of the stage 3 value functions in Appendix A, the households' and the firms' stage 2 surpluses correspond to:

$$\Delta_h(m_j, d_j, k_j) \equiv u(q_j) - \phi[\hat{m}_j + \hat{d}_j(1+i_d)],$$
$$\Delta_f(m_j, d_j, k_j) \equiv -c(q_j) - q_j + \phi[\hat{m}_j + \hat{d}_j(1+i_d)],$$

respectively. Taking as given the prices (ϕ, i_d) and the household's and the firm's inventories (m_j, d_j, k_j), the bargaining problem solves:

$$(q_j, \hat{m}_j, \hat{d}_j) \in \arg\max_{q_j, \hat{m}_j, \hat{d}_j} \ \Delta_h(m_j, d_j, k_j), \tag{4}$$
$$\text{s.t. } (1-\theta)\Delta_h(m_j, d_j, k_j) = \theta \Delta_f(m_j, d_j, k_j), \tag{5}$$
$$\text{s.t. } \hat{m}_j \in [0, m_j], \hat{d}_j \in [0, d_j], q_j \in [0, k_j], \tag{6}$$

where (5) represents the proportional surplus-splitting rule and (6) the households' and firms' feasibility constraints. Combining (4)-(6) yields the updated bargaining problem:

$$\max_{q_j} \ \Delta_h(m_j, d_j, k_j) \equiv \theta[u(q_j) - c(q_j) - q_j], \tag{7}$$
$$\text{s.t. } \Phi(q_j) = \phi(\hat{m}_j + \hat{d}_j(1+i_d)), \tag{8}$$
$$\text{s.t. } \hat{m}_j \in [0, m_j], \hat{d}_j \in [0, d_j], q_j \in [0, k_j], \tag{9}$$

where $\Phi(q_j) \equiv (1-\theta)u(q_j) + \theta[c(q_j) + q_j]$. In short, firms and households solve a two-sided constrained optimization problem with (i) an inventory constraint on the firm side and (ii) a liquidity constraint on the household side.[13]

Definition 1. *An equilibrium of the bargaining game in stage 2 is a set of strategies, $(q_j, \hat{m}_j, \hat{d}_j)$, such that the terms of trade, $(q_j, \hat{m}_j, \hat{d}_j)$, are a solution to the bargaining problem, (7)-(9).*

[12] As shown in Lebeau (2020), bargaining problems with two-sided capacity constraints are sensitive to the bargaining solution. While for non-monotone solutions, e.g. generalized Nash (1950) bargaining, trade can break down due to strategic portfolio choices (agents undercutting each other to zero), for monotone solutions such as Kalai (1977), agents coordinate and gains from trade are realized in equilibrium.

[13] Note that a two-sided hold-up problem can arise: inefficiently low investment (and thus low trade volume) due to ex-ante sunk costs before entering negotiations. A hold-up problem occurs when investors do not earn the total return on an ex-ante costly investment, causing them to under-invest in the first place. This can occur if, for example, the investor bearing the cost (costly capital/ liquidity accumulation) does not have all of the bargaining power. See Bethune et al. (2019) and Wright et al. (2020) for a detailed discussion of two-sided hold-up problems.

Distinguishing between $j \in \{O, I\}$, for $i_d \geq 0$, the solution to the bargaining problem is a pair $(q_O(k_O, m_O), \hat{m}_O(k_O, m_O))$ in *outside* meetings, and a pair $(q_I(k_I, d_I), \hat{d}_I(k_I, d_I))$ in *inside* meetings, satisfying:

$$q_O, \hat{m}_O = \begin{cases} q^*, \Phi(q^*)/\phi & \text{if} \quad q^* \leq \min\{k_O, \Phi^{-1}(\phi m_O)\} \\ k_O, \Phi(k_O)/\phi & \text{if} \quad k_O \leq \min\{q^*, \Phi^{-1}(\phi m_O)\} \\ \Phi^{-1}(\phi m_O), m_O & \text{if} \quad m_O \leq \min\{\Phi(k_O)/\phi, \Phi(q^*)/\phi\}, \end{cases} \tag{10}$$

and:

$$q_I, \hat{d}_I = \begin{cases} q^*, \Phi(q^*)/(\phi(1+i_d)) & \text{if} \quad q^* \leq \min\{k_I, \Phi^{-1}(\phi d_I(1+i_d))\} \\ k_I, \Phi(k_I)/(\phi(1+i_d)) & \text{if} \quad k_I \leq \min\{q^*, \Phi^{-1}(\phi d_I(1+i_d))\} \\ \Phi^{-1}(\phi d_I(1+i_d)), d_I & \text{if} \quad d_I \leq \min\{\Phi(k_I)/(\phi(1+i_d)), \Phi(q^*)/(\phi(1+i_d))\}, \end{cases} \tag{11}$$

respectively, with the firms' and households' stage 2 surpluses corresponding to:

$$\Delta_h(m_j, d_j, k_j) = \theta[u(q_j) - c(q_j) - q_j],$$
$$\Delta_f(m_j, d_j, k_j) = (1-\theta)[u(q_j) - c(q_j) - q_j].$$

Three cases can occur. (i) Suppose neither the firm's capacity constraint nor the household's liquidity constraint binds. In that case, the firm produces $q = q^*$ and receives $\Phi(q^*)$, where q^* denotes the ex-post efficient quantity determined in Section 2.2. (ii) If the household's liquidity constraint binds, then the household transfers all liquid assets, i.e., $\hat{m}_O = m_O$ and $\hat{d}_I = d_I$ and receives $q_O = \Phi^{-1}(\phi m_O)$ and $q_I = \Phi^{-1}(\phi d_I(1+i_d))$, respectively. (iii) If, in turn, the firm's capacity constraint binds, then the firm produces $q_O = k_O$ and $q_I = k_I$ and receives $\phi \hat{m}_O = \Phi(q_O)$ and $\phi \hat{d}_I(1+i_d) = \Phi(q_I)$ in exchange.

2.5 Stage 1: Banking and Firm Capacity Choice

To determine the firm's production capacity k_j in stage 2, we must first characterize the terms of the loan contracts in the stage 1 banking sector. Recall that firms cannot accumulate liquid assets ex-ante (in stage 3) and finance investments with bilateral loans issued by commercial banks in an OTC loan market.[14] Banks, in turn, finance nominal loans supplied to firms by issuing nominal deposits to households in a competitive deposit market.[15] The two markets are connected through

[14]For frameworks in which firms finance capital with a combination of liquid assets and bilaterally bargained-over bank loans see Rocheteau et al. (2018), Jackson and Madison (2022), and Bethune et al. (2022).

[15]In line with Berentsen et al. (2007), banks are intermediaries exclusively, i.e., they cannot produce numéraire goods in stage 3, and get linear utility from consumption. Importantly, however, they do not need to acquire funds before conducting investments but can

a competitive interbank market in which banks can borrow and lend funds at the interbank market rate $i_b \in \mathbb{R}$. One can interpret the interbank rate, i_b, as the shadow price of funds within large banks, i.e., banks with multiple branches and/ or distinct loan and deposit departments.[16]

Firstly, we determine the bank's deposit demand and characterize the bank's optimal investment decision. Secondly, we determine the terms of the loan contracts conditional on the firm's type, $j \in \{O, I\}$. Thirdly, we determine the interbank market equilibrium, characterizing the banks' balance sheet allocations.

Deposit Demand: Starting with the bank's deposit demand, for a given set of prices (ϕ, i_d, i_b), the bank's profit maximization problem solves:

$$\max_{d_b, \sigma^M \in [0,1]} \phi d_b \Big[(1-\sigma^M)(1+i_b) + \sigma^M - \psi - (1+i_d) \Big], \tag{12}$$

where d_b denotes the bank's deposit demand, σ^M is the share of deposits held as fiat money, $1-\sigma^M$ is the share of deposits lent to the interbank market at the rate i_b, and ψ is a proportional bank operation cost characterizing the spread between lending and deposit rates.[17] The constraint $\sigma^M \in [0,1]$ rules out negative investments. Solving (12), the first-order conditions:

$$\begin{aligned} &-(1+i_d) - \psi + (1-\sigma^M)(1+i_b) + \sigma^M \geq 0 \quad (= 0 \text{ if } d_b > 0), \\ &-(1+i_b) + 1 \geq 0 \quad (= 0 \text{ if } \sigma^M > 0), \end{aligned}$$

imply $i_d = i_b - \psi \geq 0$ if $\sigma^M = 0$, and $i_d = i_b - \psi = 0$ if $\sigma^M > 0$, with the bank's deposit demand $d_b \in (0, \infty)$ satisfying the market clearing condition $\eta_I d_I = d_b$, where $\eta_I d_I$ denotes the *inside*-households' deposit supply. Thus, given the competitive nature of the deposit market, banks transfer the returns generated on the interbank market, net the bank operation cost, to depositors and earn zero profits in equilibrium. Furthermore, since the households' deposit supply $d_I = 0$ for $i_d < 0$ there is a zero lower bound on interest rates.

Loan Supply: Next, let us determine the terms of the loan contract, $(k_j, i_{l,j})$ – loan size k_j and lending rate $i_{l,j}$ – bilaterally negotiated between banks and type-$j \in \{O, I\}$ firms according to

issue liquid liabilities (inside money) to finance loans, assuming capital suppliers accept them.

[16] This formalization is in line with Drechsler et al. (2017) and Choi and Rocheteau (2023) stating that "*the decision of how many deposits to raise at a given branch is independent of the decision of how many loans to make at that bank.*" - (Drechsler et al., 2017, p.1844).

[17] In line with Drechsler et al. (2017) and Choi and Rocheteau (2023), this cost can be interpreted as the cost of operating a deposit franchise. It includes salaries, rent, advertising, and miscellaneous expenditures to serve and attract depositors.

Kalai's (1977) proportional bargaining rule.[18] Following the linearity of the stage 3 value functions in Appendix A and taking as given the allocations $(q(m_j,d_j,k_j),\ \hat{m}_j(m_j,d_j,k_j),\ \hat{d}_j(m_j,d_j,k_j))$ in stage 2, let:

$$\Omega_f(q_j,\hat{m}_j,\hat{d}_j) = (1-\theta)[u(k_j) - c(k_j) - k_j] - k_j i_{l,j}, \tag{13}$$

$$\Omega_b(q_j,\hat{m}_j,\hat{d}_j) = k_j(i_{l,j} - i_b), \tag{14}$$

denote the firm's and the bank's surplus, respectively, with $\Omega_f(q_j,\hat{m}_j,\hat{d}_j) + \Omega_b(q_j,\hat{m}_j,\hat{d}_j)$ being the total surplus bargained over. Starting with the firms' surplus in (13), obtaining a bank loan, and thus the production capacity k_j, yields a surplus in stage 2. The bank's surplus in (14) is the interest payment collected from the firm in stage 3 net the cost of borrowing funds from the interbank market. The terms of the loan contract solve:

$$(k_j, i_{l,j}) \in \arg\max\ (1-\theta)[u(k_j) - c(k_j) - k_j] - k_j i_{l,j}, \tag{15}$$

$$\text{s.t. } \nu[(1-\theta)[u(k_j) - c(k_j) - k_j] - k_j i_{l,j}] = (1-\nu)k_j(i_{l,j} - i_b), \tag{16}$$

$$\text{s.t. } k_j(1+i_{l,j}) \leq \chi(1-\theta)[u(k_j) - c(k_j) - k_j], \tag{17}$$

where $\nu \in [0,1]$ denotes the bank's bargaining power. Equation (16) represents the proportional surplus splitting rule, and (17) is the firm's borrowing constraint. Debt limits are imposed exogenously following Kiyotaki and Moore (1997) with the pledgeability parameter $\chi \in [0,1]$ representing the share of the firm's stage 2 surplus a bank can recover if the firm defaults on its loan obligation (loan-to-value ratio).[19]

Distinguishing between outside and inside firms $j \in \{I, O\}$, the terms of the loan contract, $(k_O, i_{l,O})$ and $(k_I, i_{l,I})$, satisfy:

$$k_j = \min\{\bar{k}_j, \underline{k}_j\}, \tag{18}$$

$$i_{l,j} = \frac{\nu(1-\theta)[u(k_j) - c(k_j) - k_j]}{k_j} + (1-\nu)i_b, \tag{19}$$

with the firm's capacities (loan sizes), $\bar{k}_j$ and $\underline{k}_j$, solving:

$$(1-\theta)[u'(\bar{k}_j) - c'(\bar{k}_j) - 1] - i_b = 0, \tag{20}$$

[18] Given the competitive price of capital $\phi_k = 1$, a nominal loan purchases $\phi l_j = k_j$ units of capital from the capital supplier, characterizing the loan size $\phi l_j = k_j$.

[19] Alternatively, one can consider a case in which, instead of the stage 2 surplus, firms pledge a share of their stage 2 cash-flows, $\chi\phi[\hat{m}_j + \hat{d}_j(1+i_d)] \equiv \chi\Phi(k_j)$, to the bank. The two approaches yield similar results.

and:

$$\underline{k}_j + (1-\nu)\underline{k}_j i_b = (\chi - \nu)(1-\theta)[u(\underline{k}_j) - c(\underline{k}_j) - \underline{k}_j], \tag{21}$$

respectively, conditional on whether (17) binds or not. Consider two cases. Suppose the firm's collateral constraint does not bind. In that case, according to (20), the firm's marginal stage 2 surplus equals the interbank rate, with the loan size $\bar{k}_j$ solving (20) for both outside and inside firms. Vice versa, if the firm's collateral constraint (17) binds, then the loan size corresponds to $\underline{k}_j < \bar{k}_j$ solving (21). In both cases, according to (19), the bank's interest payment collected from the firm, $k_j i_{l,j}$, is equal to the bank's share of the firm's stage 2 surplus plus the firm's share of the interbank market interest payment. Taking as given i_b, the smaller the loan size, the higher the lending rate, $\partial i_{l,j}/\partial k_j < 0$. Furthermore, $\partial i_{l,j}/\partial i_b > 0$, and thus there exists a positive pass-through from the interbank rate to the bank lending rate.

Interbank Market Equilibrium: Let us now characterize the market clearing condition in the interbank market to determine the equilibrium interbank market rate i_b. Firstly, recall that there is a measure one of households, firms, and banks. Let the banks' aggregate deposit demand $D_b(i_b)$ be the *inside* households' deposit supply $D_b(i_b) = \eta_I d_I(i_b)$ with $d_I(i_b) = \Phi(q_I)/(\phi(1+i_d))$ and $i_d = i_b - \psi$. The banks' aggregate loan supply, in turn, is given by $L_b(i_b) = \eta_O l_O(i_b) + \eta_I l_I(i_b)$ with $l_j(i_b) = k_j(i_b)/\phi$ and $k_j(i_b)$ solving (20) if (17) does not bind and (21) if (17) binds. Equating the aggregate demand to the aggregate supply $D_b(i_b) = L_b(i_b)$, i.e.,:

$$D_b(i_b) \equiv \eta_I \frac{\Phi(q_I(i_b))}{1 + i_b - \psi} = \eta_O k_O(i_b) + \eta_I k_I(i_b) \equiv L_b(i_b), \tag{22}$$

with $\Phi(q_j) \equiv (1-\theta)u(q_j) + \theta[c(q_j) + q_j]$ solves for the equilibrium interbank rate, i_b. Figure 5 visualizes the interest rate channel with the red dashed line representing the bank lending rate $i_{l,j}$ solving (19), the black solid line the interbank market rate i_b solving (22), and the blue dotted line the deposit rate, $i_d = i_b - \psi$, capturing the key stylized facts in Figure 2.

3 Monetary Equilibrium

This section characterizes the general equilibrium of the model. Incorporating the solutions to the agents' bargaining problems, we determine the households' stage 3 portfolio choices and the firms' stage 1 capacity choices. Since trade in stage 2 occurs subject to two-sided capacity constraints, households take into account the firms' production capacity when choosing their liquidity holdings,

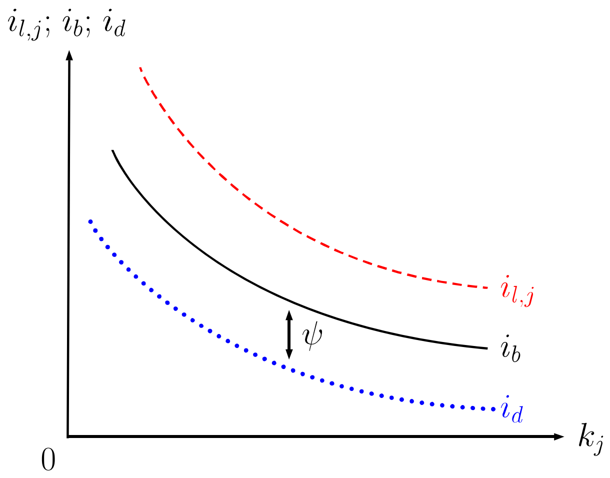


Figure 5: Bank interest rate channel

and vice versa. Thus, considering pure strategies, an equilibrium is characterized by production capacities k_j and liquidity holdings (m_j, d_j) such that k_j is the firm's best response to the households carrying (m_j, d_j), and (m_j, d_j) is the households' best response to the firms' production capacity k_j.[20]

Definition 2. *A monetary equilibrium is a list of portfolios in stage 3 $\{m_O, d_O, m_I, d_I\}$, stage 2 allocations $\{q_O, \hat{m}_O, \hat{d}_O, q_I, \hat{m}_I, \hat{d}_I\}$, stage 1 allocations $\{d_b, i_d, k_O, k_I, i_{l,O}, i_{l,I}, i_b\}$, and aggregate balances M, D_b, and L_b such that:*

(i) (m_O, d_O) and (m_I, d_I) solve (1) and (3);

(ii) $(q_O, \hat{m}_O, \hat{d}_O)$ and $(q_I, \hat{m}_I, \hat{d}_I)$ solve (10) and (11);

(iii) (d_b, i_d), $(k_O, k_I, i_{l,O}, i_{l,I})$, and i_b solve (12), (15)-(17), and (22); and

(iv) the market clearing conditions satisfy $M = \eta_O m_O + \eta_I m_I + \sigma^M d_b$, $D_b = \eta_O d_O + \eta_I d_I$, $L_b = \eta_O l_O + \eta_I l_I$, and $D_b = L_b$.

3.1 Households' best response

Let us start with the households' choice of fiat money m_O and bank deposits d_I, taking as given the firms' production capacities k_O and k_I. Revisiting the portfolio choice problems in (1) and (3), and incorporating the allocations of the bargaining game, (10) and (11), as well as the fact that

[20]Given the concavity of the surplus functions $\Delta_h(m_j, d_j, k_j)$ and $\Delta_f(m_j, d_j, k_j)$ all equilibria are in pure strategies, i.e., mixed strategies are ruled out.

$i_d = i_b - \psi \geq 0$, the $j \in \{O, I\}$ households choose m_O and d_I solving:

$$m_O \in \arg\max -(\phi_{-1}/\beta - \phi)m_O + \Delta_h(m_O, k_O), \tag{23}$$

and:

$$d_I \in \arg\max -(\phi_{-1}/\beta - \phi(1+i_d))d_I + \Delta_h(d_I, k_I), \tag{24}$$

respectively, with the households' stage 2 surpluses corresponding to:

$$\Delta_h(m_O, k_O) = \begin{cases} \theta[u(q^*) - c(q^*) - q^*] & \text{if} \quad q^* \leq \min\{k_O, \Phi^{-1}(z_O)\} \\ \theta[u(k_O) - c(k_O) - k_O] & \text{if} \quad k_O \leq \min\{q^*, \Phi^{-1}(z_O)\} \\ \theta[u(\Phi^{-1}(z_O)) - c(\Phi^{-1}(z_O)) - \Phi^{-1}(z_O)] & \text{if} \quad \Phi^{-1}(z_O) \leq \min\{k_O, q^*\}, \end{cases}$$

and:

$$\Delta_h(d_I, k_I) = \begin{cases} \theta[u(q^*) - c(q^*) - q^*] & \text{if} \quad q^* \leq \min\{k_I, \Phi^{-1}(z_I)\} \\ \theta[u(k_I) - c(k_I) - k_I] & \text{if} \quad k_I \leq \min\{q^*, \Phi^{-1}(z_I)\} \\ \theta[u(\Phi^{-1}(z_I)) - c(\Phi^{-1}(z_I)) - \Phi^{-1}(z_I)] & \text{if} \quad \Phi^{-1}(z_I) \leq \min\{k_I, q^*\}, \end{cases}$$

with $z_O \equiv \phi m_O$ and $z_I \equiv \phi d_I(1+i_d)$. For any capacity k_O and k_I, the households' surpluses $\Delta_h(m_O, k_O)$ and $\Delta_h(d_I, k_I)$ increase in m_O and d_I until the households' liquidity holdings are sufficient to purchase either the firms capacity or q^*, provided the firm's capacity supports the latter. Once sufficient, the surplus remains the same, as visualized in Figure 6.

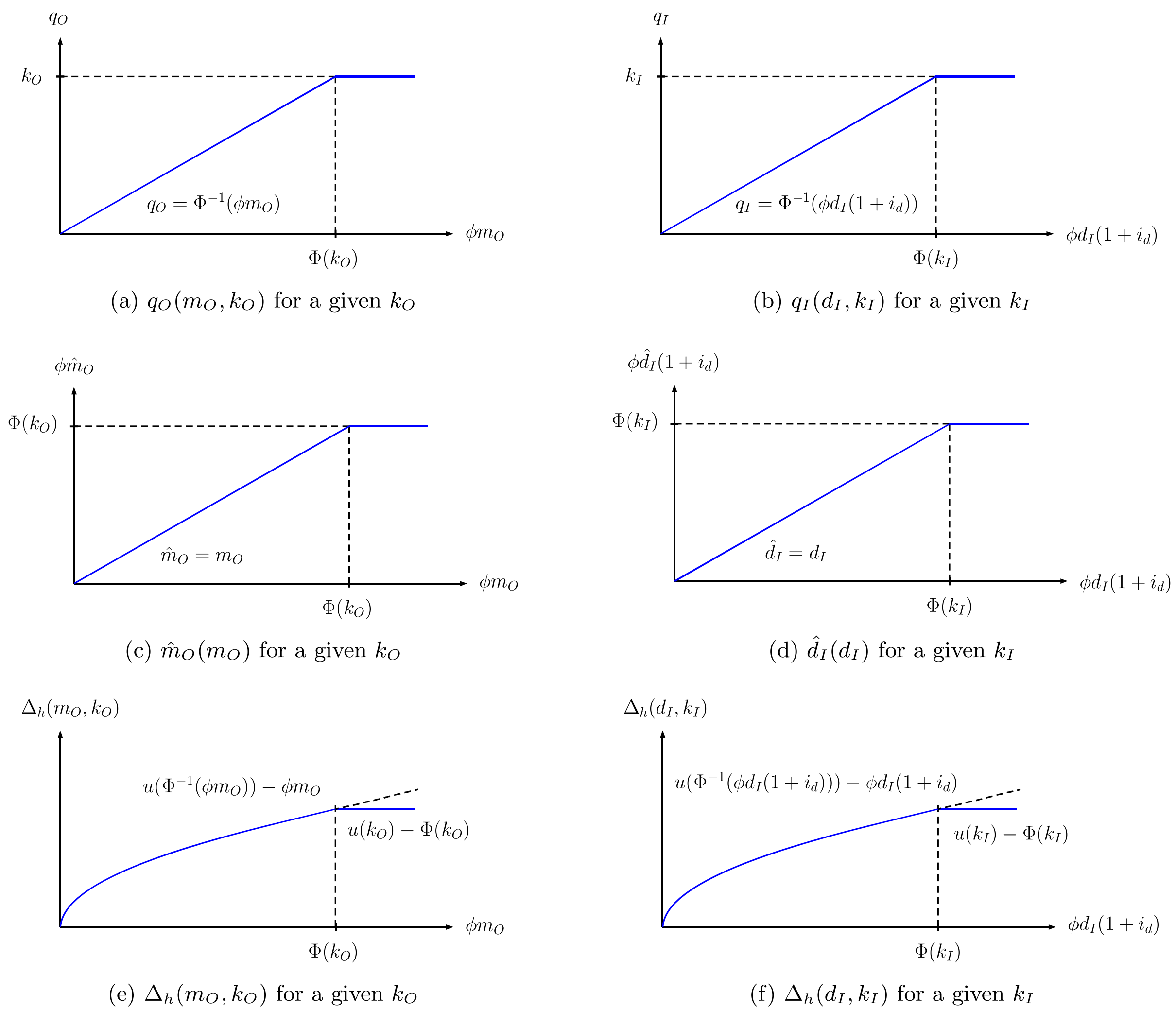
Thus, replacing m_O and d_I in (23) and (24) with $m_O = \Phi(q_O)/\phi$ and $d_I = \Phi(q_I)/(\phi(1+i_d))$ from (10) and (11), and solving yields:

$$i = \frac{\theta[u'(q_O^h) - c'(q_O^h) - 1]}{(1-\theta)u'(q_O^h) + \theta[c'(q_O^h) + 1]}, \tag{25}$$

and:

$$\frac{1+i}{1+i_d} - 1 = \frac{\theta[u'(q_I^h) - c'(q_I^h) - 1]}{(1-\theta)u'(q_I^h) + \theta[c'(q_I^h) + 1]}, \tag{26}$$

with $i \equiv \gamma_m/\beta - 1$ denoting the Fisher rate, and $q_O^h \leq q^*$ and $q_I^h \leq q^*$ (holding with equality if $i = 0$ and $i = i_d$, respectively) denoting the households' choices of real balances assuming the firm's capacity constraint does not bind. Thus, a household's best response to the firms' capacities k_O



(a) $q_O(m_O, k_O)$ for a given k_O

(b) $q_I(d_I, k_I)$ for a given k_I

(c) $\hat{m}_O(m_O)$ for a given k_O

(d) $\hat{d}_I(d_I)$ for a given k_I

(e) $\Delta_h(m_O, k_O)$ for a given k_O

(f) $\Delta_h(d_I, k_I)$ for a given k_I

Figure 6: Household allocations as a function of (m_O, d_I) for a given (k_O, k_I)

and k_I is to carry enough real balances $\phi m_O = \Phi(q_O(k_O))$ and $\phi d_I(1+i_d) = \Phi(q_I(k_I))$ to satisfy:

$$\tilde{q}_O(k_O) = \min\{k_O, q_O^h\} \quad \text{and} \quad \tilde{q}_I(k_I) = \min\{k_I, q_I^h\}, \tag{27}$$

i.e., enough real balances to either purchase k_j or q_j^h, depending on whether the firm's capacity constraint binds or not.

3.2 Firms' best response

Let us now determine the firms' capacity choice, k_O and k_I, taking as given the households' liquidity holdings, (m_O, d_O) and (m_I, d_I). Contrary to the households' portfolio choices in the competitive stage 3 (choosing quantities taking prices i and i_d as given), firms acquire capital from competitive capital suppliers using bank loans, where the terms of the loan contracts (both prices $i_{l,j}$ and quantities k_j) are bilaterally bargained over in a decentralized market. Revisiting the firm's bargaining problem in stage 1, (15)-(17), and incorporating the stage 2 allocations, $(q_O, \hat{m}_O)$ and $(q_I, \hat{d}_I)$, in (10) and (11), a firm chooses $((k_O, i_{lO}), (k_I, i_{l,I}))$ to maximize its stage 1 surplus solving:

$$(k_j, i_{l,j}) \in \arg\max \ \Delta_f(m_j, d_j, k_j) - k_j i_{l,j}, \tag{28}$$

$$\text{s.t. } k_j i_{l,j} = \nu \Delta_f(m_j, d_j, k_j) + (1-\nu) k_j i_b, \tag{29}$$

$$\text{s.t. } k_j(1 + i_{l,j}) = \chi \Delta_f(m_j, d_j, k_j), \tag{30}$$

with the firms' stage 2 surpluses corresponding to:

$$\Delta_f(m_O, k_O) = \begin{cases} (1-\theta)[u(q^*) - c(q^*) - q^*] & \text{if } \ q^* \leq \min\{\underline{k}_O, \Phi^{-1}(z_O)\} \\ (1-\theta)[u(\underline{k}_O) - c(\underline{k}_O) - \underline{k}_O] & \text{if } \ \underline{k}_O < \min\{q^*, \Phi^{-1}(z_O)\} \\ (1-\theta)[u(\Phi^{-1}(z_O)) - c(\Phi^{-1}(z_O)) - \Phi^{-1}(z_O)] & \text{if } \ \Phi^{-1}(z_O) < \min\{\underline{k}_O, q^*\}, \end{cases}$$

and:

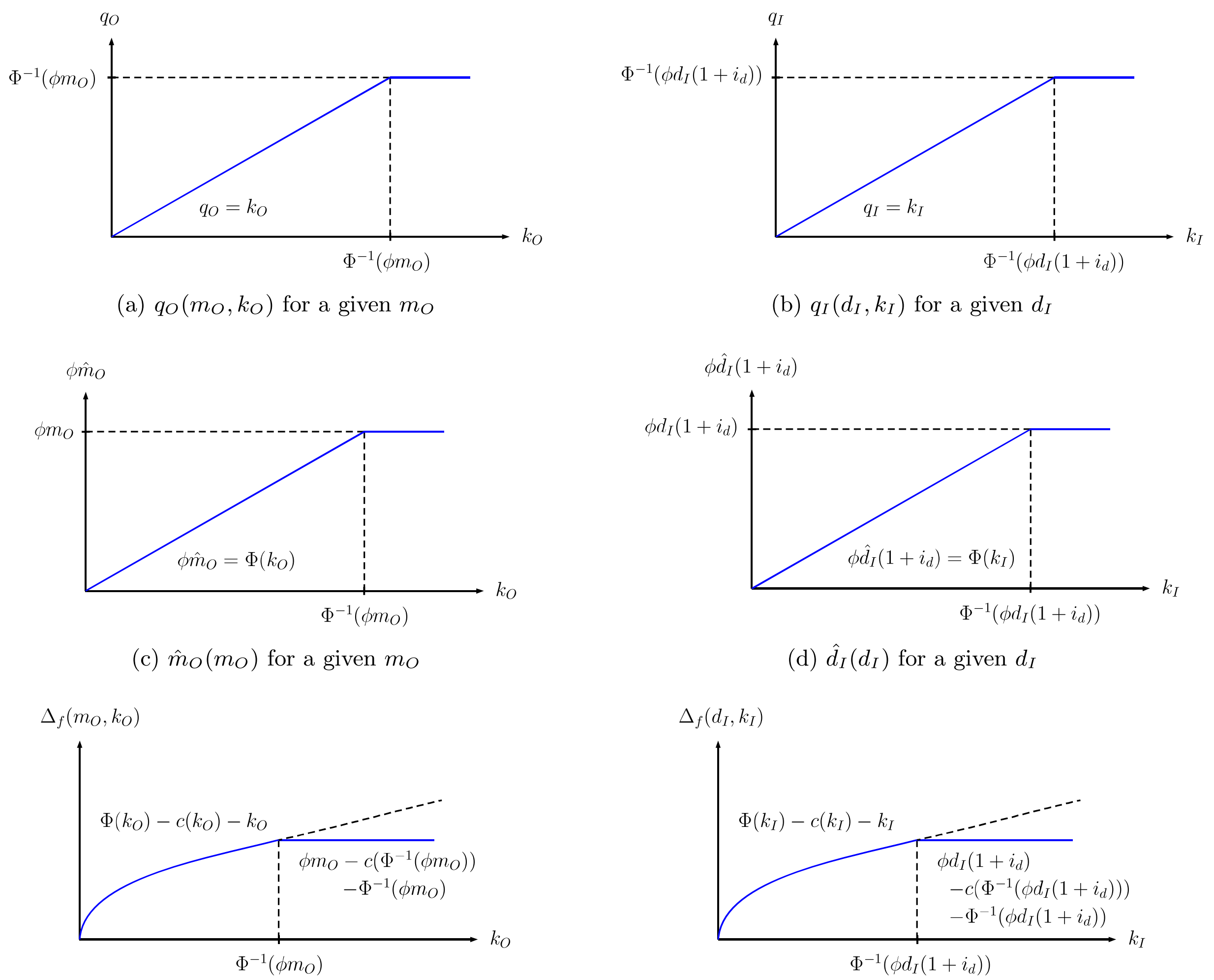
$$\Delta_f(d_I, k_I) = \begin{cases} (1-\theta)[u(q^*) - c(q^*) - q^*] & \text{if } \ q^* \leq \min\{\underline{k}_I, \Phi^{-1}(z_I)\} \\ (1-\theta)[u(\underline{k}_I) - c(\underline{k}_I) - \underline{k}_I] & \text{if } \ \underline{k}_I < \min\{q^*, \Phi^{-1}(z_I)\} \\ (1-\theta)[u(\Phi^{-1}(z_I)) - c(\Phi^{-1}(z_I)) - \Phi^{-1}(z_I)] & \text{if } \ \Phi^{-1}(z_I) < \min\{\underline{k}_I, q^*\}, \end{cases}$$

with $z_O \equiv \phi m_O$, $z_I \equiv \phi d_I(1 + i_d)$, and $\underline{k}_j$ solves (21). For any liquidity holdings, m_O and d_I, the firms' stage 2 surpluses, $\Delta_f(m_O, k_O)$ and $\Delta_f(d_I, k_I)$, increase in the capacities k_O and k_I until the firms' output q_O and q_I either meets the households' liquidity holdings or q^*, provided the households' liquidity holdings support the latter. Figure 7 visualizes the quantities traded, the households' payments, and the firms' surpluses for any k_O and k_I taking as given the households' liquidity holdings m_O and d_I.

Let us now characterize the firms' capacity choice. Assuming the households' liquidity constraints do not bind, i.e., $q_O < \Phi^{-1}(\phi m_O)$ and $q_I < \Phi^{-1}(\phi d_I(1 + i_d))$, the solutions to (28) yield the lending rates:

$$i_{l,j} = \frac{\nu(1-\theta)[u(q_j^f) - c(q_j^f) - q_j^f]}{q_j^f} + (1-\nu) i_b \geq 0,$$

for $j \in \{O, I\}$ with i_b solving (22), q_j^f solving $q_j^f = q^*$ if (17) does not bind, and q_j^f solving (21) if (17) binds. On the other hand, if the households' liquidity constraints bind, then the firm's



(a) $q_O(m_O, k_O)$ for a given m_O

(b) $q_I(d_I, k_I)$ for a given d_I

(c) $\hat{m}_O(m_O)$ for a given m_O

(d) $\hat{d}_I(d_I)$ for a given d_I

(e) $\Delta_f(m_O, k_O)$ for a given m_O

(f) $\Delta_f(d_I, k_I)$ for a given d_I

Figure 7: Firm allocations as a function of (k_O, k_I) for a given (m_O, d_I)

capacity choice corresponds to $q_O = \Phi^{-1}(\phi m_O)$ and $q_I = \Phi^{-1}(\phi d_I(1+i_d))$, yielding the firms' best responses to the households' liquidity holdings:

$$\tilde{k}_O(m_O) = \min\{\Phi^{-1}(\phi m_O), q_O^f\} \quad \text{and} \quad \tilde{k}_I(d_I) = \min\{\Phi^{-1}(\phi d_I(1+i_d)), q_I^f\}. \tag{31}$$

Thus, a firm either acquires enough capital to purchase the household's entire liquidity holdings or the maximum amount obtainable with q_j^f, depending on which one is smaller. Given the heterogeneity in the type-$j \in \{O, I\}$ households' liquidity holdings, capacities (and thus lending rates) vary across firms, corroborating the empirical evidence by Mora (2014) attributing the dispersion in lending rates to differences in the lender's bargaining position.

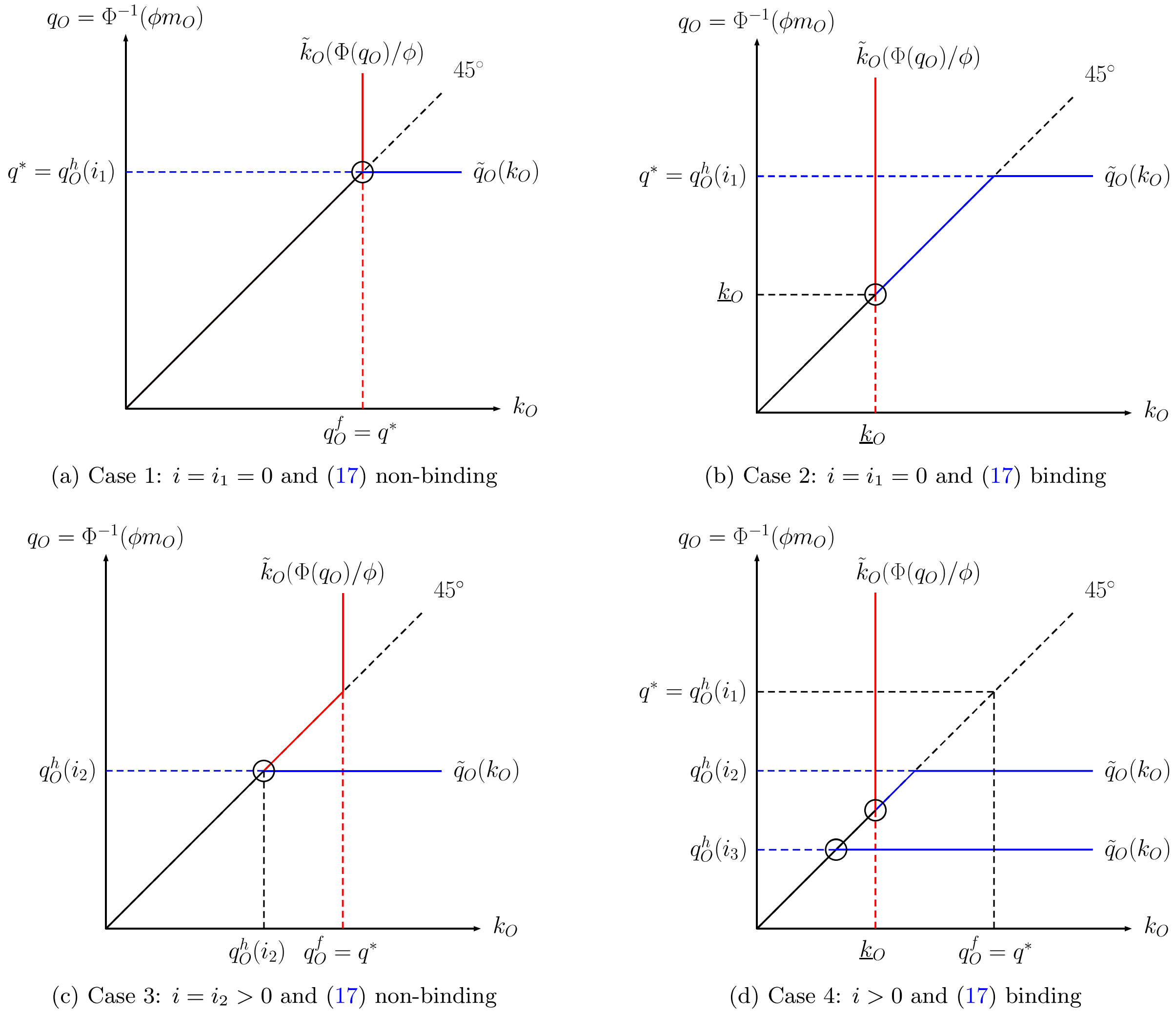


Figure 8: Best response functions: outside meetings

3.3 Equilibrium Characterization

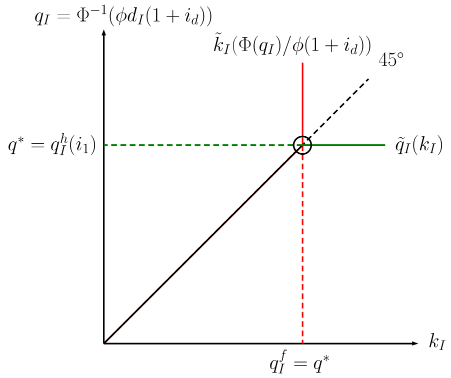
Using (27) and (31), a pair $(q_O(k_O), m_O)$ and $(q_I(k_I), d_I)$ is an equilibrium if $k_O = \tilde{k}_O(m_O)$ and $m_O = \Phi(\tilde{q}_O(k_O))/\phi$, and $k_I = \tilde{k}_I(d_I)$ and $d_I = \Phi(\tilde{q}_I(k_I))/(\phi(1+i_d))$. Given $\Phi(q_O) = \phi m_O$ and $\Phi(q_I) = \phi d_I(1+i_d)$, choosing m_O and d_I is equivalent to choosing q_O and q_I, and thus the households' best response functions are given by $q_O = \tilde{q}_O(k_O)$ and $q_I = \tilde{q}_I(k_I)$, while the firms' best response functions are given by $k_O = \tilde{k}_O(m_O) = \tilde{k}_O(\Phi(q_O)/\phi)$ and $k_I = \tilde{k}_I(\Phi(q_I)/(\phi(1+i_d)))$.

Let us start with the *outside* meetings, characterized by $(q_O, k_O) = (\tilde{q}_O(k_O), \tilde{k}_O(\Phi(q_O)/\phi))$. Given (27), the household's best response satisfies $\tilde{q}_O = \min\{\tilde{k}_O, q_O^h\}$ with $\partial q_O^h/\partial i < 0$, where $q_O^h = q^*$ if $i = 0$ (Friedman rule). Vice versa, the firm's best response satisfies $\tilde{k}_O = \min\{\tilde{q}_O, q_O^f\}$

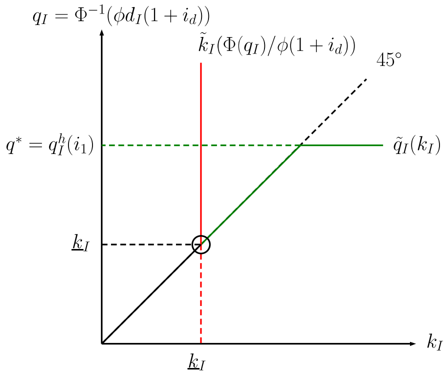
with $q_O^f = q^*$ if (17) does not bind, and $q_O^f = \underline{k}_O$ solving (21) if (17) binds with $\underline{k}_O$ increasing with the pledgeability parameter, $\partial \underline{k}_O / \partial \chi > 0$. Consider the four cases, visualized in Figure 8 by plotting k_O against q_O, distinguishing between three nominal interest rates, $i_3 > i_2 > i_1 = 0$, and (17) binding or not. Let us start with the benchmark case in which $i = i_1 = 0$ and (17) non-binding. In this case, neither the households nor the firms are constrained in their liquidity and capital accumulation and equilibrium consumption is first-best, $q_O = q^*$. Second, consider the case in which $i = i_1 = 0$ but (17) binds, and thus $q_O = \underline{k}_O < q^*$ due to the firm's binding collateral constraint. Third, if $i > 0$ and (17) does not bind, then equilibrium consumption is constrained by the household's liquidity, $q_O = q_O^h < q^*$, and therefore a reduction of the nominal interest rate improves allocations. Lastly, if $i > 0$ and (17) binds, then $q_O = \min\{q_O^h, \underline{k}_O\} < q^*$. In this case, if $\underline{k}_O > q_O^h$ (case $i = i_3$), then reducing inflation improves allocations analog to case three. Contrarily, if $\underline{k}_O \leq q_O^h$ (case $i = i_2$), then equilibrium consumption is constrained by the firm's capacity, and thus there emerges an effective lower bound (ELB) – a threshold nominal interest rate below which easing monetary policy does not improve equilibrium allocations.

Let us now consider the *inside* meetings, characterized by $(q_I, k_I) = (\tilde{q}_I(k_I), \tilde{k}_I(\Phi(q_I)/(\phi(1 + i_d))))$. The household's best response satisfies $\tilde{q}_I = \min\{\tilde{k}_I, q_I^h\}$ with q_I^h solving (26), and the firm's best response satisfies $\tilde{k}_I = \min\{\tilde{q}_I, k_I^f\}$ with $k_I^f = q^*$ if (17) does not bind, and $k_I^f = \underline{k}_I$ solving (21) if (17) binds. Analog to the outside meetings, let us distinguish between four cases. Figure 9 visualizes the results by plotting k_I against q_I, and contrasts them to q_O and k_O in the outside meetings. First and foremost, if the nominal interest rate is at the Friedman rule $i = i_1 = 0$, then $q_I^h = q^*$, and thus the equilibrium consumption is pinned down by the firm's capacity, q_I^f (case 1 and 2), analog to the equilibrium in outside meetings. If $i = i_2 > 0$ and $q_I^f = q^*$, then $q_I \in (q_O, q^*]$, as the interest on deposits $i_d > 0$ (partially) compensates the depositor for the inflation tax, where $q_I^h = q^*$ if $i_d \geq i$, and $q_I^h < q^*$ if $i_d < i$ given (26). If $i = i_3 > 0$ with $q_O^h(i_3) < \underline{k}_O$ and $q_I^f = \underline{k}_I$ (i.e., (17) binds), then $q_I = q_I^h(i_3)$ if $q_I^h(i_3) < \underline{k}_I$ (case 4a) and $q_I = \underline{k}_I$ if $q_I^h(i_3) \geq \underline{k}_I$ (case 4b). While easing monetary policy increases output in case 4a, in case 4b the equilibrium allocations are pinned down by the firm's capacity constraint, resulting in an ELB rendering conventional monetary policy ineffective.

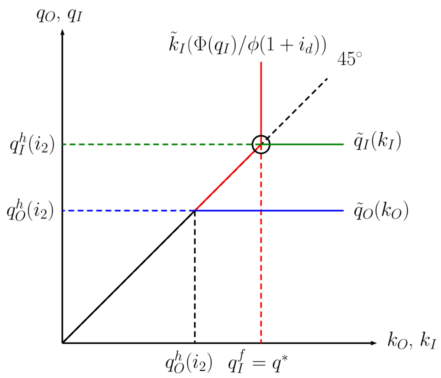
Next, we assess the model quantitatively to identify for what parameterizations the ELB emerges in equilibrium. To do so, we calibrate the model to the United States economy and distinguish between regimes with different financial market microstructures and firm characteristics.



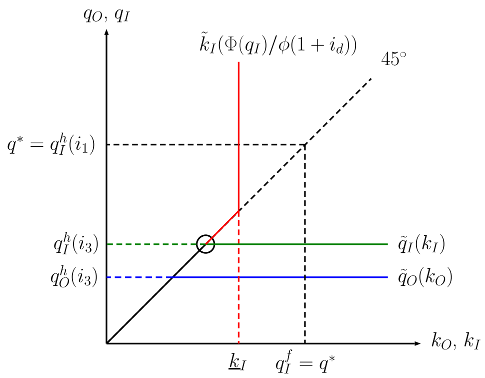
(a) Case 1: $i = i_1 = 0$ and (17) non-binding



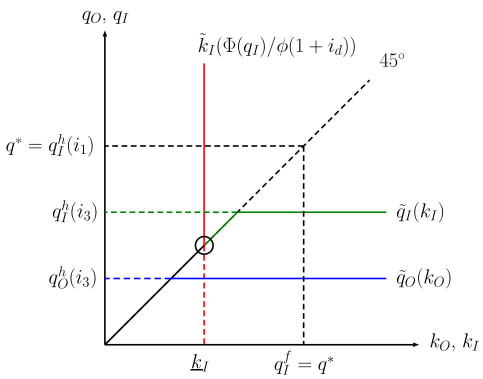
(b) Case 2: $i = i_1 = 0$ and (17) binding



(c) Case 3: $i = i_2 > 0$ and (17) non-binding



(d) Case 4a: $i = i_3 > 0$ and (17) binding



(e) Case 4b: $i = i_3 > 0$ and (17) binding

Figure 9: Best response functions: inside meetings

4 Numerical Analysis

4.1 Calibration

We set a period in the model to be a month in calendar time. Several parameters are set exogenously to their direct empirical counterparts or following the literature. The discount factor β is

Parameter	Description	Value
	Externally Calibrated Parameters	
β	Discount Rate	0.9975
i	Nominal Interest Rate (Annual)	5.2%
η	Measure of Cash-only Firms	0.3568
ξ	Firms' Cost Elasticity	2
C	Firms' Cost Coefficient	0.5
	Internally Calibrated Parameters	
B	Household's Utility Coefficient	1.012
γ	Household's Utility Elasticity	0.148
θ	Households' Goods Market Bargaining Power	0.048
ν	Banks' Credit Market Bargaining Power	0.143
ψ	Banks' Operating Cost	0.008

Table 2: Calibrated Parameters.

set to 0.9975, consistent with a 3% annual real return, as in Bethune et al. (2020) and Herrenbrueck (2019). We set the annual nominal rate i to 5.2% based on the AAA nominal corporate bond yield, as in Jackson and Madison (2022). The measure η of outside firms is set to 35.68% to match the empirical fraction of transactions completed with cash in the US economy in 2017; for the empirical evidence see Greene and Stavins (2018) and for a similar calibration choice see Banet and Lebeau (2022). We follow the vast majority of the New Monetarist literature and work with a power cost function of the form $c(q) = Cq^{\xi}$ with the elasticity ξ set to 2 and the coefficient C to 0.5. Finally, we calibrate the model assuming that the collateral constraint (equation 17) does not bind. We explore the impact of a binding collateral constraint on monetary policy transmission in the numerical exercises of Section 4.2 below. The top panel of Table 2 summarizes the externally set parameter values.

To complete the model's parameterization, we need to specify the functional form of households' preferences. As in much of the New Monetarist literature, e.g. Berentsen et al. (2011) or Bethune et al. (2020), we work with the CRRA form for the households' utility of the decentralized market good: $u(q) = Bq^{1-\gamma}/(1-\gamma)$. In total, this leaves us with five parameters to be calibrated through the lens of the model: the households' utility function parameters, B and γ; the bargaining shares in the labor and product market, θ and ν; and, finally, the cost banks face to operate a deposits franchise, ψ.

To pin down these parameters, we employ various empirical moments. First, regarding the utility function parameters, we follow the standard practice in the New Monetarist literature. We

Target	Data	Model
Average Money Holdings over GDP	22.53%	23.80%
Elasticity of Money Holdings wrt AAA rate	-0.51	-0.52
Product Market Markup	1.39	1.34
Bank Prime Loan Rate	6.28%	6.28%
National Deposit Rate	0.27%	0.26%

Table 3: Targets and Model Performance

target the average money holdings as a fraction of GDP to pin down B (Bethune et al., 2020), and the elasticity of money holdings with respect to the return on AAA bonds (Berentsen et al., 2011) using the data shared by Lucas and Nicolini (2015) to pin down γ. Next, to pin down θ, we target an average markup of 1.39 in the product market, following Bethune et al. (2020). Finally, we use data from the Board of Governors of the Federal Reserve System to determine ν and ψ. In particular, the long-run average of the bank prime loan rate pins down ν, while ψ is set such that the deposit rate in the model is equal to the long-run average of the national deposit rate. As can be seen in Table 3, the model matches the empirical targets very well. We use the calibrated model as a laboratory for various quantitative exercises in the following section.

4.2 Numerical Exercises

Our goal is to understand the impact of the financial sector on the transmission of monetary policy to output and investment. To this end, we consider changes in the nominal interest rate i in three different model versions: i) the benchmark model with a non-binding collateral constraint (equation 17), ii) a model in which the value of χ is such that the collateral constraint binds, and iii) a model with a binding collateral constraint as well as a larger value of the banks' bargaining power ν. The benchmark model corresponds to a "normal times" regime in which the financial sector is a veil that adjusts to changes in fundamentals and policy variables. The model with the binding collateral constraint corresponds to a "credit rationing" regime in which financial frictions impede investment. As a result, firms do not have unlimited access to funding and the banking sector matters for the real economy. Finally, motivated by the evidence presented in Section 1.1, we add an increase in banks' bargaining power to the credit rationing regime. In this model version, not only do firms face investment constraints but also financial intermediaries take a larger share of the surplus produced in the real economy. Comparing the allocations in the two credit rationing regimes with the allocation in the benchmark case captures the model's implications regarding the impact of the financial sector on monetary policy transmission.

Variable	Benchmark Model	Credit Rationing	CR with High Bank Power
IM Ouput	0.2340	0.2334	0.2284
OM Output	0.1850	0.1850	0.1850
DM Output	0.2165	0.2161	0.2129
Interbank Rate	1.98%	1.94%	1.57%
Lending Rate	6.92%	6.89%	9.17%
Deposit Rate	1.19%	1.14%	0.77%

Table 4: Steady state levels of the main endogenous variables in the three model versions. The Benchmark Model is the calibrated model with a non-binding collateral constraint (equation 17). For the Credit Rationing model we choose the minimum value of χ that makes the collateral constraint bind, while all other parameters are at their calibrated levels. The CR with High Bank Power features a binding collateral constraint as well as a 50% greater value of the bank bargaining power in the credit market ν.

We begin with the main features of the steady state allocations of the three model versions while parameters are at their calibrated values. Table 4 summarizes the values of the main endogenous variables across models: the inside meetings (IM) output q_I; the outside meetings (OM) output q_O; the aggregate decentralized market (DM) output, $\eta_O q_O + \eta_I q_I$; the interbank rate i_b; the aggregate lending rate, $\eta_O i_{l,O} + \eta_I q_{l,I}$; and the deposit rate, i_d. In the benchmark model, $q_O < q_I$ because the purchasing power of households paying with deposits exceeds the purchasing power of households paying with fiat money, due to $i_d > 0$.

For the credit rationing version of the model, we choose the minimum value of χ that makes the collateral constraint bind. As the collateral constraint becomes binding, firms borrow less from the banks and purchase a lower level of capital from the capital suppliers. Under the calibrated parameters, this leads to a lower level of output produced and purchased in the inside meetings, whereas outside meetings remain unaffected. The reason is that outside meetings feature lower output and, thus, χ has to decline further for the outside firms' collateral constraint to bind. In total, the aggregate decentralized output is a weighted sum of the output in the inside and outside meetings and, as a result, it is lower in the credit rationing than in the benchmark model. Finally, all interest rates in the economy are lower under credit rationing, which reflects the firms' lower demand for loans.

Next, the credit rationing with high bank power model version features a binding collateral constraint as well as a 50% greater value of the bank bargaining power ν. The larger ν translates into a higher lending rate. As a result, the firms' demand for loans decreases and yielding a reduction in output in the decentralized market. In sum, higher bargaining power of banks in the credit market amplifies the impact of the credit rationing on the real economy.

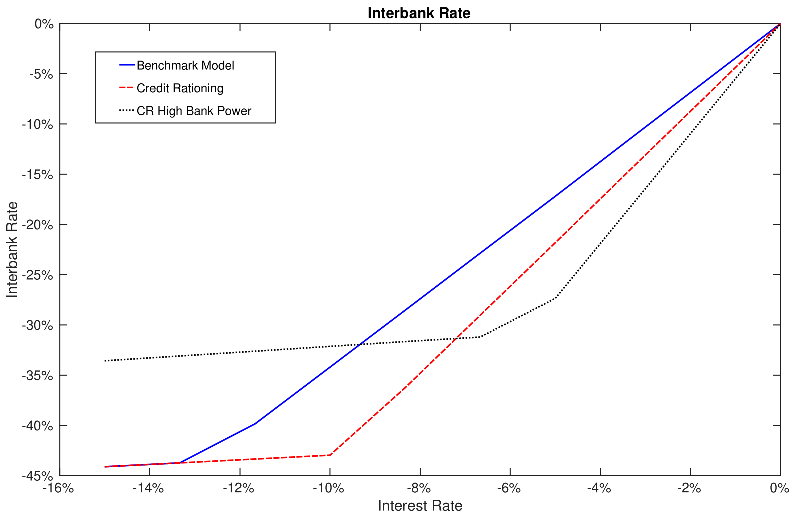


Figure 10: Responses of the interbank rate to monetary policy easing in the three model versions.

We now turn to the analysis of monetary policy transmission in the three model versions. Specifically, we show how the steady state values of endogenous variables respond to monetary policy easing (declines in the nominal rate i).[21] We present results as percentage changes from their corresponding levels at the calibrated 5.2% annual interest rate. Figure 10 depicts the responses of the interbank rate, Figure 11 the responses of aggregate decentralized output, and Figure 12 the responses of the rest of the endogenous variables (inside and outside meetings output, as well as deposit and aggregate lending rate).

The first main result is that the model features positive interest rate pass-through: all interest rates in the economy decline in response to monetary easing (Figure 10 and the bottom panels of Figure 12). It is instructive to explain the channels behind this pass-through to shed light on the model's mechanisms. As the nominal rate declines, the households' purchasing power increases, which has a two-sided effect on the interbank market: it raises both the value of deposits supplied by the inside households and the firms' loan demand. In equilibrium, the supply effect dominates and the interbank rate declines in response to drops in the nominal rate in all model versions. Both the deposit and aggregate lending rate are functions of the interbank rate and follow its behavior, making the model consistent with the empirical evidence presented in Figure 2 of Section 1.1.

Figure 11 and the top panels of Figure 12 describe how the decline in interest rates affects the production and trade of output in the decentralized market. As nominal rates decrease, the larger value of household liquidity and the lower credit cost boost decentralized output in all three models.

[21] Focusing on steady states is the approach followed by Berentsen et al. (2011) and is common practice in search theory (see, e.g., Hornstein et al. (2005), Petrosky-Nadeau (2013), Ljungqvist and Sargent (2017), and Gabrovski et al. (2025*a*), among others).

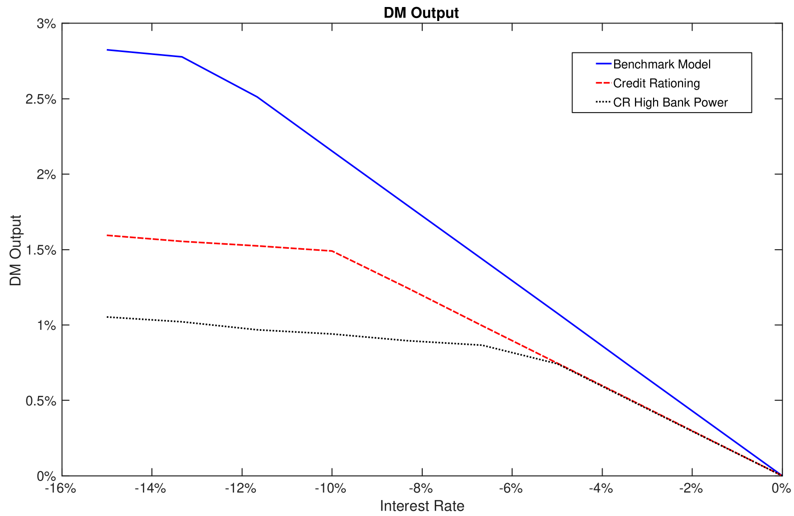


Figure 11: Responses of the output produced and traded in the decentralized market to monetary policy easing in the three model versions.

This describes the second main result our analysis: the model generates a reverse Mundell-Tobin effect, with interest rates and output being inversely related.[22]

The most striking result, however, is that the responses of all interest rates and types of output in all three model versions feature a *kink*: there is a threshold nominal rate below which the transmission of monetary policy is significantly weaker. For nominal rates lower than this effective lower bound (ELB), the impact of monetary easing on the banking sector and the real economy becomes negligible. We should highlight that this bound is not zero: all interest rates are strictly positive in all experiments considered. Moreover, the ELB is not the outcome of some modified version of the Friedman rule in the model: output does not reach its social optimum in any of the experiments considered.

The mechanism behind the effective lower bound in the model lies in the workings of the interbank and credit markets. Under monetary easing, both the value of household deposits (the interbank market supply) and firm loans (the interbank market demand) increase. Crucially, banks' market power in the credit market along with their operating costs create a wedge between the interest banks pay on household deposits and the lending rates they charge firms, limiting banks' willingness to expand credit despite cheaper funding costs. This effect is also amplified by the fact that only an η_I fraction of households supply deposits but all firms demand loans. For a reduction

[22] The original Mundell-Tobin effect is expressed as a relationship between inflation and capital accumulation. In our model, inflation moves one-to-one with the nominal rate and capital moves one-to-one with output. Thus, we express the Mundell-Tobin effect as a relationship between the nominal rate and output. See Section 1.1 for a summary of the empirical literature on the Mundell-Tobin effect.

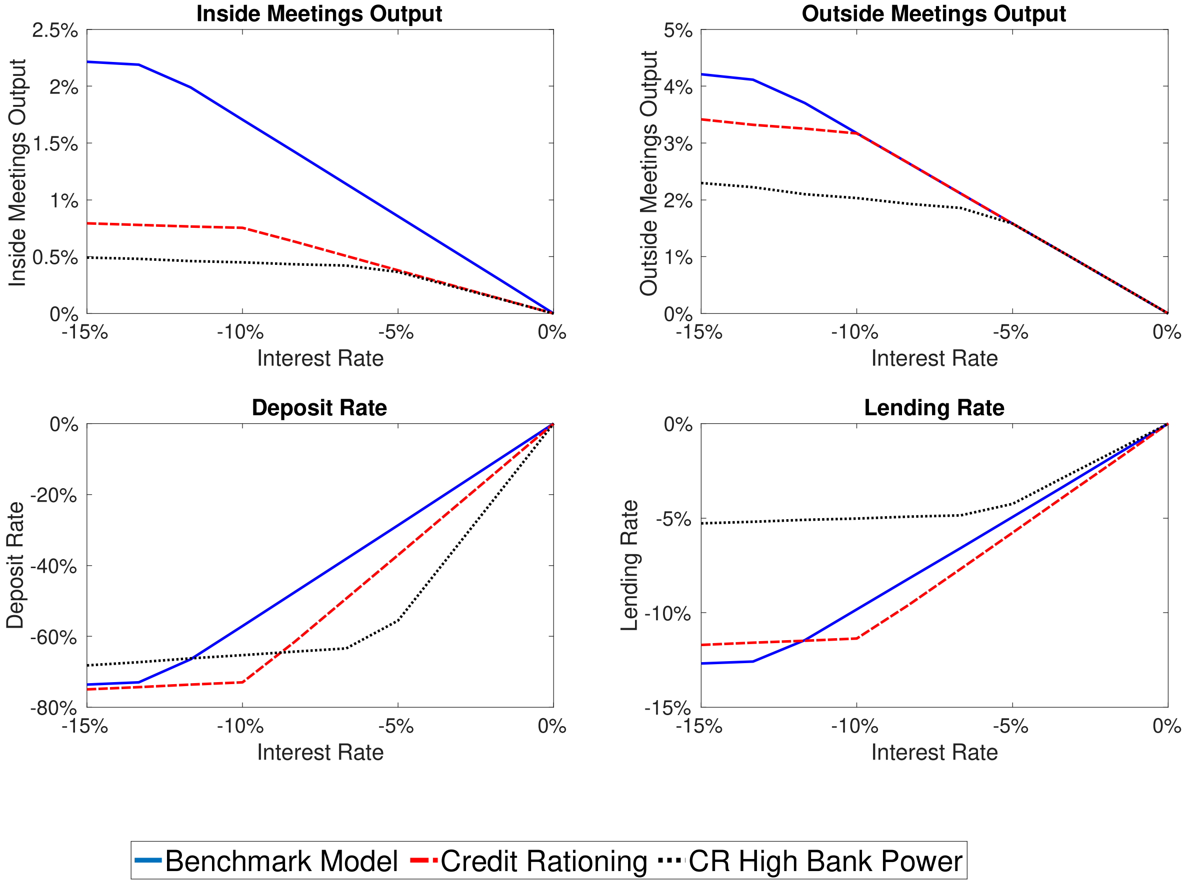


Figure 12: Responses of endogenous variables to monetary policy easing in the three model versions.

in nominal rates close to the calibrated level, the increased loan supply in the interbank market can sustain the increased loan demand of firms driven by the increased households' purchasing power. At the kink point though, the deposit supply cannot sustain further increases in the loan demand, causing a liquidity shortage in the interbank market. As a result, when the nominal rate decreases below the kink point, interest rates as well as decentralized output barely change; that is, conventional monetary policy becomes ineffective and the economy enters a liquidity trap.

Importantly, the effectiveness of monetary policy depends on the features of the banking sector. That is, the effective lower bound kicks in closer to the benchmark level of the nominal rate under credit rationing and high bank power. In these model versions, fewer loans are issued at higher rates. As a result, a nominal rate reduction increases the loan supply of banks by less than in the benchmark model, causing monetary policy to become ineffective at higher nominal rates. This result provides a policy-relevant lesson with an important implication: the effectiveness of monetary policy depends on financial conditions in general and the bargaining power of intermediaries in particular. Under financial restraint and when intermediaries extract a lot of surplus, the effectiveness of traditional monetary easing declines: the financial sector does not transmit the additional liquidity to firms. Hence, our results provide a rationalization of the non-standard monetary policies, such as quantitative easing and forward guidance, that have been followed by central banks around the world during the 2007-2009 financial crisis and the Covid recession.

5 Conclusion

This paper develops a general equilibrium framework in which the effective lower bound (ELB) on nominal interest rates arises endogenously from frictions in the financial sector. In contrast to standard models that treat the ELB as an exogenous constraint—often pinned near zero—we show that its level depends on the structure of the credit market. In our model, financially constrained firms rely on bank loans to fund investments. In general, when nominal interest rates fall, higher household purchasing power increases firms' demand for credit and, consequently, their output. Below the ELB, however, banks do not expand lending sufficiently, causing the economy to hit a ELB at a positive nominal rate. Thus, monetary policy can become ineffective well before rates approach zero.

Our analysis highlights how both financial sector characteristics and firm-level constraints shape the monetary transmission mechanism. The interaction of bank market power, operating costs, and firm collateral constraints determines the extent to which lower nominal rates pass through to credit supply and real activity. In "normal times," when collateral constraints are slack, policy remains effective at relatively low interest rates. But in tighter credit environments—especially when banks hold significant bargaining power—the ELB rises, monetary pass-through weakens, and output becomes unresponsive to further easing.

These insights carry important implications for the design and conduct of monetary policy. First, they offer a rationale for the limited effectiveness of conventional tools near the ELB, and underscore the relevance of non-standard policies such as quantitative easing. Second, they point to the financial sector—not merely interest rate levels—as a key determinant of monetary effectiveness. When banks act as bottlenecks in credit allocation, monetary and macroprudential policies should be viewed as complements. Ensuring well-functioning financial intermediation, especially during downturns, may be critical to restoring the potency of standard monetary instruments.

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Appendix

A. Value Functions

Households: Households of type $j \in \{O, I\}$ enter stage 3 with financial wealth $\omega_{h,j} = m_j + d_j(1 + i_d)$ consisting of fiat money m_j and bank deposits d_j. They choose their consumption of the numéraire good x, and the next period's money holdings m'_j to maximize their lifetime utility according to:

$$W_h(\omega_{h,j}) = \max_{x, m'_j} x + \beta Z_h(m'_j), \tag{A.1.}$$

$$\text{s.t. } \; x + \phi m'_j = \phi \omega_{h,j} + T, \tag{A.2.}$$

where $\beta Z_h(m'_j)$ is the discounted continuation value of entering stage 1 with fiat money, and (A.2.) is the budget constraint. Plugging (A.2.) into (A.1.) and solving yields the first-order and envelope conditions $\beta Z_{h,m'_j} = \phi$, $W_{h,m_j} = \phi$, and $W_{h,d_j} = \phi(1 + i_d)$. Since $W_h(\omega_{h,j})$ is linear in current financial wealth, a household's future money holdings, m'_j, are independent of the current wealth $\omega_{h,j}$, and all households enter stage 1 with the same money holdings. In stage 1, households enter the banking sector and make their deposit decision according to:

$$Z_h(m_j) = \max_{d_j \in [0, m_j]} V_h(m_j - d_j, d_j),$$

with the value function of a household entering stage 2 with (m_j, d_j) equal to:

$$V_h(m_j, d_j) = u[q(m_j, d_j, k_j)] + W_h(\omega_{h,j} - \hat{m}_j(m_j, d_j, k_j) - \hat{d}_j(m_j, d_j, k_j)), \tag{A.3.}$$

where $q(m_j, d_j, k_j)$ corresponds to the household's stage 2 consumption as a function of the household's liquidity, m_j and d_j, and the firm's production capacity, k_j, where $\hat{m}_j \in [0, m_j]$ and $\hat{d}_j \in [0, d_j]$ represent the household's liquidity constraints. Combining (A.1.)-(A.3.) yields the household's portfolio choice problem:

$$\max_{m'_j, d'_j} -(\phi/\beta - \phi')m'_j - (\phi' - \phi'(1 + i'_d))d'_j + \Delta_h(m'_j, d'_j, k'_j), \tag{A.4.}$$

with the $j \in \{O, I\}$ type households' stage 2 surplus equal to:

$$\Delta_h(m_O, k_O) \equiv u[q(m_O, k_O)] - \phi \hat{m}_O(m_O, k_O),$$
$$\Delta_h(m_I, d_I, k_I) \equiv u[q(m_I, d_I, k_I)] - \phi[\hat{m}_I(m_I, d_I, k_I) + (1 + i_d)\hat{d}_I(m_I, d_I, k_I)],$$

respectively, determined via bilateral bargaining in Section 2.4. The first two terms of (A.4.) represent the opportunity cost of holding fiat money and bank deposits.

Firms: A type $j \in \{O, I\}$ firm enters stage 1 without capital or financial assets and obtains a loan from a bank to accumulate capital k_j at the competitive price ϕ_k from the capital supplier:

$$Z_f(0) = V_f(k_j, l_j),$$

with the terms of the loan contract determined via bilateral bargaining in Section 2.5. The firm's value function entering stage 2 is:

$$V_f(k_j, l_j) = -c(q(m_j, d_j, k_j)) + W_f(k_j - q(m_j, d_j, k_j), \omega_{f,j}),$$

with $q_j(m_j, d_j, k_j)$ corresponding to the firm's stage 2 output as a function of the firm's production capacity and the household's liquidity, and $\omega_{f,j} = \hat{m}_j + \hat{d}_j(1 + i_d) - l_j(1 + i_{l,j})$ the firm's financial wealth consisting of fiat money and bank deposits received as payment from households, $\hat{m}_j$ and $\hat{d}_j$, and loan obligations to the bank. Following the linearity of $W_f(k_j, \omega_{f,j})$, i.e.,

$$W_f(k_j, \omega_{f,j}) = x \quad \text{s.t.} \quad x = \phi\omega_{f,j} + \phi_k k_j,$$

the type $j \in \{O, I\}$ firm's stage 2 surplus corresponds to:

$$\begin{aligned} \Delta_f(m_O, k_O) &\equiv [-c(q_O) + W(k_O - q_O, l_O + \hat{m}_O)] - W(k_O, l_O) \\ &= -c(q_O) - q_O + \phi\hat{m}_O, \end{aligned}$$

and

$$\begin{aligned} \Delta_f(m_I, d_I, k_I) &\equiv [-c(q_I) + W(k_I - q_I, l_I + \hat{m}_I + \hat{d}_I)] - W(k_I, l_I) \\ &= -c(q_I) - q_I + \phi[\hat{m}_I + (1 + i_d)\hat{d}_I], \end{aligned}$$

with $\hat{m}_O \in [0, m_O]$, $\hat{m}_I \in [0, m_I]$, and $\hat{d}_I \in [0, d_I]$ respectively. The terms of trade are determined via bilateral bargaining in Section 2.4.

Taking as given the firm's surplus in stage 2, the type $j \in \{O, I\}$ firm's surplus in stage 1 is:

$$\begin{aligned} \Omega_{f,O} &\equiv V(k_O, l_O) - V(0, 0) \\ &= \Delta_h(m_O, k_O) - \phi l_O i_{l,O}, \end{aligned}$$

and:

$$\begin{aligned}\Omega_{f,I} &\equiv V(k_I, l_I) - V(0,0)\\ &= \Delta_h(m_I, k_I) - \phi l_I i_{l,I},\end{aligned}$$

with $i_{l,j} \in \mathbb{R}_+$ denoting firm j's lending rate and $\phi l_j = k_j$ (given $\phi_k = 1$) the loan size, both bargained over between the bank and the firm in the OTC loan market in stage 1 (see section 2.5).

Capital suppliers: The value function of a capital supplier entering stage 3 with financial wealth $\omega_s = l_f$, i.e., the payment received by the firm, is given by:

$$W_s(\omega_s) = x_s + \beta Z_s(0) \quad \text{s.t.} \quad x_s = \phi l_f \geq 0, \tag{A.5.}$$

with the value function of stage 1 equal to:

$$Z_s(0) = \max_k \{-k + \phi_k k + W_s(\omega_s)\}. \tag{A.6.}$$

Combining (A.5.)-(A.6.) and solving yields the price of capital $\phi_k = 1$.

Banks: Banks enter stage 3 with non-negative financial wealth $\omega_b = m_b + l_b(1+i_l) - d_b(1+i_d)$ consisting of fiat money m_b, loans l_b, and deposits d_b satisfying:

$$W_b(\omega_b) = x + \beta Z_b(0) \quad \text{s.t.} \quad x = \phi\omega_b \geq 0$$

In stage 1, a bank maximizes its profits by deciding on the amount of deposits it wants to attract and how it allocates them between fiat money and bank loans according to:

$$\begin{aligned}Z_b(0) &= \max_{d_b, m_b, l_b} W_b(\omega_b),\\ &\quad \text{s.t.} \quad m_b = \sigma^M d_b,\\ &\quad \text{s.t.} \quad l_b = (1-\sigma^M) d_b,\end{aligned}$$

and the market-clearing condition $d_b = \eta_I d_I$, with $\sigma^M \in [0,1]$ denoting the share of deposits held in fiat money.

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