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Monetary Policy and the Credit Rationing Effects of Liquidity

By *Jonathan Swarbrick*

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Abstract

This paper studies monetary policy in a New Keynesian economy with frictional bank lending, rationalising evidence that lending conditions can remain tight despite liquidity injections. The model features a policy trade-off in which increases in banking sector liquidity can incentivise *more lending* by lowering the overnight rate and the marginal cost of funds, but can also incentivise *less lending* by compressing bank margins as interest rates approach the policy floor, worsening adverse selection and credit rationing. As a result, quantitative easing can exert a contractionary effect when the economy is away from the effective lower bound, with outcomes depending on borrower risk and the size of the programme. However, both channels raise inflation expectations, so liquidity policies are expansionary on net at the lower bound. Optimal policy features a deflation bias under credit rationing, while commitment to future accommodation eases current credit conditions and implies gradualism in quantitative tightening.

JEL: E5, E44, G21

Keywords: Monetary policy, quantitative easing, small business lending, credit rationing, bank liquidity

1 Introduction

The monetary policy environment has evolved considerably since the global financial crisis (GFC). Many central banks expanded their menu of policies and now routinely use balance sheet policies to respond to crises. Yet the effects of these policies remain imperfectly understood,

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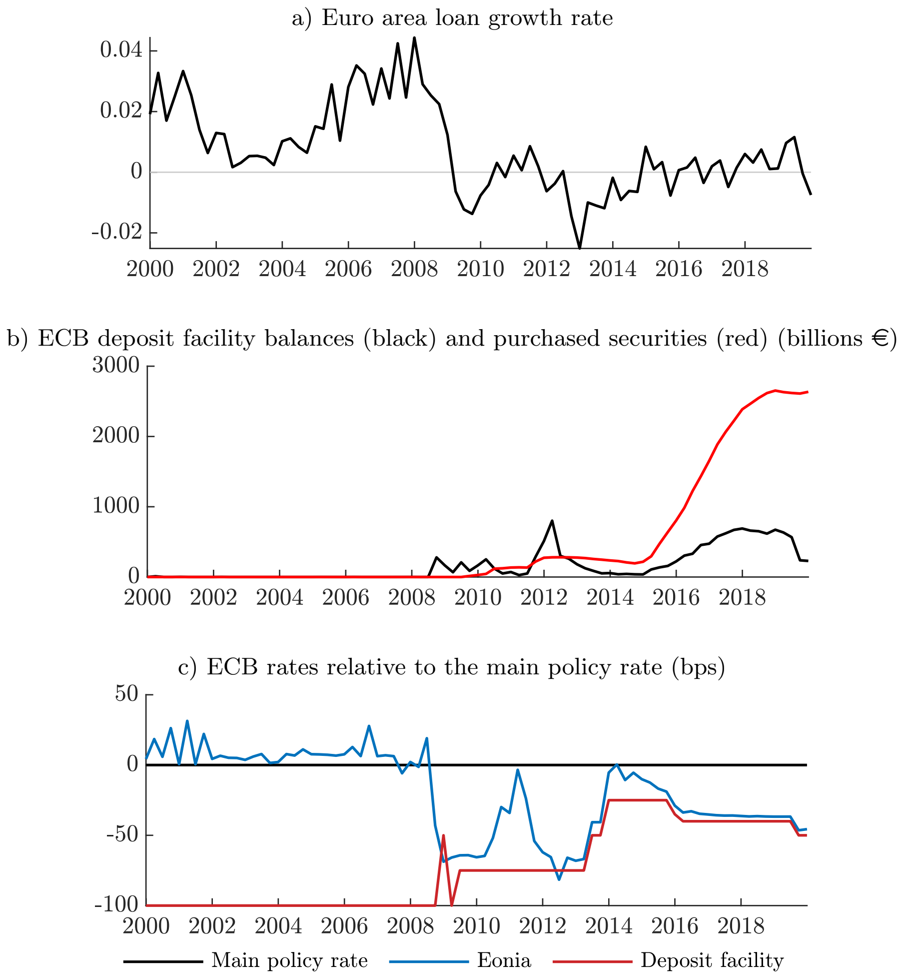

Figure 1: Source: ECB. Loans are those to euro area NFCs reported by MFIs. Purchased securities includes the stock of securities purchased as part of the various asset purchase programmes since 2009.

with implications both for the design of future interventions and for the unwinding of central bank balance sheets. While these policies have led to a dramatic rise in central bank balance sheets and banking sector liquidity, a central challenge has been ensuring that these expansions translate into improved lending conditions, particularly for small businesses. In practice, despite a sharp increase in banking sector liquidity after the GFC, euro area banks remained reluctant to lend to small businesses, even after the easing of the sovereign debt crisis. Figure 1 illustrates this disconnect, showing weaker lending (panel a) alongside a substantial and sustained rise in excess reserve balances (panel b).

This poses a puzzle as most macroeconomic theories of bank lending predict that liquidity expansions drive more lending and investment (see, e.g., Kashyap et al., 2002; Adrian and Shin, 2010; Carpenter et al., 2014), yet recent evidence suggests this is not always the case. For example, Diamond et al. (2024) find that bank reserve injections crowded out bank loans in the US, while Iyer et al. (2014) show that greater euro area liquidity from ECB balance sheet policies led to liquidity hoarding rather than increased small-business lending.[1]

In this paper, we rationalise this evidence using a New Keynesian macroeconomic model in which information frictions in small business lending interact with monetary policy implementation. The key mechanism is that policy-induced changes in bank profitability alter the opportunity cost of lending, generating endogenous credit rationing even in the presence of abundant liquidity.[2] The lending friction prevents banks from observing the risk characteristics of small firms in the economy, creating an adverse selection problem in credit markets. This generates a well-established effect, explored by Ikeda (2020) and Swarbrick (2023) in relation to the GFC, under which banks ration credit and build up excess reserves when firm risk is high. Crucially, this adverse selection channel links monetary policy implementation to lending incentives. The key determinant is the spread to the floor: the gap between the market rate and the rate paid on reserves, which equals the policy corridor absent liquidity operations. Because reserves offer a risk-free outside option, this spread determines the opportunity cost of extending risky loans, and therefore the incentive to ration credit to small businesses.

An important implication is that a narrowing of the interest corridor, such as that caused by the effective lower bound on nominal interest rates (ELB) in the euro area (Figure 1, panel c), can increase the incentive to ration small business loans, offsetting the expansionary effects of low rates and the unconventional policy measures. This creates a tension whereby when the bank funding rate falls, activity may be stimulated through the standard interest rate channel, but lending incentives may simultaneously weaken as rates approach the floor, compressing net margins and increasing the relative attractiveness of holding reserves. This mechanism is supported by empirical evidence presented in Section 2, which shows that while central bank asset purchases and falling bank funding costs predict more lending in the euro area, a compression of the interest rate spread to the floor is a significant predictor of the opposite outcome.

Using a restricted version of the model, we show that a log-linear approximation takes the form of a 3+1 equation New Keynesian model, where the standard IS and Phillips curves are aug-

[1] Similarly, Acharya et al. (2019) find that the additional liquidity led to higher cash reserves and banks holding low-interest assets, but did not lead to more productive business lending. See also Gambacorta and Marques-Ibanez (2011), Joyce et al. (2011), Loutskina (2011), and Disyatat (2011). Mennuni (2025) develops a theory rationalising the buildup of excess bank liquidity.

[2] While some studies focus on bank conditions affecting the bank-lending channel of monetary policy (see, e.g., Berger and Bouwman, 2009; Cornett et al., 2011; Martin et al., 2016), our focus follows evidence that adverse selection has been an important feature of European credit markets (see Albertazzi et al., 2021).

mented by a credit wedge condition that captures endogenous lending distortions.[3] Because the credit wedge acts as a one-sided cost-push distortion, it generates a trade-off between inflation stabilisation and output stabilisation that is absent when lending is unconstrained. This trade-off has implications for optimal monetary policy design: under discretion, a policymaker facing credit rationing at the ELB optimally restrains liquidity provision to preserve bank lending margins, generating a deflation bias whose severity depends on the degree of adverse selection. Under commitment, forward guidance can ease credit conditions directly by raising expected lending profitability, and the obligation to deliver on past commitments provides a rationale for gradualism in the subsequent unwinding of balance sheet positions.

This paper makes three main contributions to our understanding of monetary policy transmission in the presence of financial frictions. First, we provide novel empirical evidence that the spread between the market rate and the policy floor predicts lending in the euro area, so that a market rate falling towards the floor predicts less lending rather than more. Second, we embed the adverse-selection banking friction of Swarbrick (2023) in a New Keynesian model in which reserve remuneration and the spread to the floor shape the opportunity cost of lending, opening a credit-rationing channel that can make liquidity provision contractionary. Third, we study optimal policy design, finding that credit rationing introduces a deflation bias as the policymaker seeks to preserve lending incentives, and that commitment to future accommodation calls for gradualism in quantitative tightening.

These contributions rest on a framework that departs from existing models in several respects. Much of the large literature examining the links between liquidity and macroeconomic outcomes focuses on how private provision of liquidity can tighten during crises, amplifying shocks and motivating a stabilising role for liquidity easing policies (see, e.g. Bernanke and Gertler, 1989; Kiyotaki and Moore, 1997; Holmström and Tirole, 1998; Adrian and Shin, 2010; Gertler and Karadi, 2011; Brunnermeier and Sannikov, 2014). Recent work has also emphasised the macroeconomic importance of adverse selection in external finance, which can distort the allocation of credit and investment (see e.g. Guo et al., 2025; Beyhaghi et al., 2026). The model developed in this paper builds on Stiglitz and Weiss's (1981) work on adverse selection, which shows how credit markets can shut down due to information frictions.[4]

[3]This shares structural similarities with Sims et al. (2023), who derive a four-equation New Keynesian model in which QE and credit shocks enter both the IS and Phillips curves.

[4]This has been extended in many papers in the years since, including, for example Bester (1985), Mankiw (1986), Williamson (1986), De Meza and Webb (1987), Besanko and Thakor (1987), House (2006), Ikeda (2020).

In contrast to models that link monetary policy transmission to borrower balance sheets through a financial accelerator, whereby monetary expansions raise asset prices and collateral values (e.g., Bernanke et al., 1999; Christiano et al., 2005), this paper abstracts from the balance sheet channel. Here, the effects of a monetary expansion are ambiguous as they depend more critically on how the expansion is implemented and how it affects banking sector liquidity, bank balance sheet composition, bank profitability, and the opportunity cost of lending. The key issue is how the shock or policy action interacts with banks' incentive to ration credit.

The theoretical model explicitly incorporates monetary policy implementation in the presence of information frictions. Banking sector liquidity is endogenous to macro-financial conditions, and banks may choose to hold excess reserves in equilibrium. Because of this, the interest rate paid on reserves affects bank profitability, liquidity demand, and ultimately lending behaviour (see also Disyatat, 2011). While standard New Keynesian models abstract from implementation details and contain no endogenous excess reserves, this framework incorporates a corridor system explicitly and studies how its design affects equilibrium outcomes.

Several existing studies explicitly examine the role of the interest rate corridor (see, e.g., Bindseil, 2000; Whitesell, 2006). These typically focus on trade-offs between interest rate volatility, interbank market activity, and monetary transmission under frictions such as interbank market search costs (Bech and Monnet, 2016) and balance sheet risk (Whitesell, 2006; Bindseil and Jabłecki, 2011). In contrast, this paper shows how the corridor affects lending conditions through a profitability channel, even in the absence of interbank frictions. The underlying mechanism is that the floor rate competes with risky lending as an alternative use of liquidity, and this trade-off shapes banks' willingness to intermediate.

By highlighting the profitability channel, the analysis also relates to recent work on the contractionary effects of negative interest rates within corridor systems (e.g., Abadi et al., 2023; Eggertsson et al., 2024), where binding deposit rate floors compress margins and weaken monetary policy transmission. In contrast, the channel here operates via adverse selection, providing a distinct profitability-based rationale for credit rationing as policy rates approach the floor.

2 Motivating evidence from the euro area

In this section we document a systematic relationship between the spread to the floor and banks' lending and reserve holdings in the euro area, controlling for macroeconomic conditions, credit risk, and ECB asset purchases. These patterns motivate the theoretical mechanism developed in the subsequent section. Focusing on the euro area is insightful due to the important role of banks in providing credit to the real economy, with around double the share of business debt in the form of bank loans compared to the United States.[5] Additionally, small and medium-sized enterprises account for around two thirds of private-sector employment in Europe compared to around one half in the United States (see Carbo-Valverde and Rodríguez-Fernández, 2016). These facts highlight the systemic importance of bank lending for credit conditions faced by small firms in the euro area.

The euro area is also a useful laboratory because the ECB's operating framework has generated rich variation in the return on reserves. The ECB operates a corridor system, and during periods of abundant liquidity the overnight interbank market rate falls below the main policy rate, so that the spread between the interbank rate and the policy floor becomes a key determinant of banks' opportunity cost of lending. As a result, changes in the floor rate and the effective spread to the floor can affect lending incentives even when conventional policy rates move little (see Figure 1, panel c).[6]

2.1 The Interbank Rate and the Policy Floor

To explore the relationship between the spread to the floor and lending conditions, we estimate the following specification using quarterly bank-level data between 2008 and 2019:

$$\ln X_{i,t} = \alpha_X + \beta_X \left(R_t - \underline{R}_t\right) + \delta_X R_t + \boldsymbol{\gamma}'_{\mathbf{X}} \cdot \mathbf{z}_t + u_{X,i,t}, \tag{2.1}$$

[5] 70% versus 35% (see Holm-Hadulla, Musso, Nicoletti and Tujula, 2022; Gambacorta, Yang and Tsatsaronis, 2014)

[6] The Federal Reserve did not operate an explicit corridor system, rather relying on open market operations to target the federal funds rate. Since 2008 the Fed began paying interest on excess reserves (IOER), moving towards a floor system. Other central banks including the Bank of England and Bank of Canada operated corridor systems and moved towards floor systems following the GFC, with corridor widths also subject to adjustment.

	$\ln Res_t$	$\ln L_t$
$s_t \equiv R_t - \underline{R}_t$	-0.172^{***} (0.062)	0.048^{***} (0.013)
R_t	0.001 (0.021)	-0.019^{***} (0.004)
Obs.	5762	4161
Adj. R^2	0.919	0.291

Notes: The spread to the floor is the interbank rate, Eonia, minus the deposit facility rate, measured per 25 basis points. Balance-sheet variables are cash and balances with central banks, $\ln Res_t$, and total loans, $\ln L_t$, from SNL Financial Fundamentals. Both columns include bank fixed effects and the controls described in the text. Standard errors, in parentheses, are clustered by bank and by quarter. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 1: Estimation results: the spread to the floor and bank balance sheets

for $X \in \{L, Res\}$, where $L_{i,t}$ is total gross loans and $Res_{i,t}$ is cash and balances at the central bank.[7] R_t is the interbank market rate (Eonia) and $\underline{R}_t$ the interest on reserves.[8] $\mathbf{z}$ is a vector of controls including GDP, inflation, credit risk, and ECB asset purchases.[9]

Table 1 reports the results. Conditional on the interbank rate, a 25 basis point wider spread predicts around 4.8% higher lending and much lower reserve balances. The estimate is stable in sign and magnitude and robust to standard errors that allow for serial correlation across quarters.[10] Because the specification conditions on the interbank rate, the coefficient on the spread isolates movements in the policy floor, the rate paid on reserves.

The loan column carries two coefficients of opposite sign. Conditional on the spread, a higher interbank rate predicts lower lending, whereas a wider spread predicts higher lending for a given interbank market rate. The two have opposing implications whenever the interbank rate moves while the floor is held fixed. Combining the two, holding the floor fixed, a 25 basis point lower interbank rate predicts around 2.9% lower lending.[11] A lower market rate predicting less lending

[7] Bank-level balance-sheet data are from S&P Global Market Intelligence (SNL Financial Fundamentals). We use all available data for banks operating in Austria, Belgium, France, Germany, Ireland, Italy, Netherlands, Portugal, Slovenia and Spain. Bank-level lending is normalised by the bank's average loan level over 2008Q1–2019Q4, and we use the average total assets as a sampling weight. We include bank fixed effects and cluster standard errors two ways, by bank and by quarter.

[8] That is, the interest rate on the ECB's standing deposit facility. Note that since October 2019 the ECB has targeted a new euro short-term rate, replacing Eonia as the interbank rate (see Nicoloso and Tsonchev, 2019, Box 1, p.23).

[9] Controls are total euro-area log real GDP and CPI (HICP) inflation, Gilchrist and Mojon's (2018) measure of credit risk of euro-area non-financial corporations, and the stock of total asset purchase programmes held by the Eurosystem for monetary policy purposes.

[10] The loan coefficient remains strongly significant under a Newey-West correction for serial correlation. Further details in Appendix D.1.

[11] The overall effect is the sum of the two channel coefficients, equivalently the coefficient on the interbank rate when the regression is written in the floor and the interbank rate rather than the spread. It equals +0.029

is the reverse of the relationship a policy easing would usually imply, and it is this comovement that motivates the mechanism developed below.

We label these the funding-cost channel and the opportunity-cost channel. Our mechanism, developed in Section 3, focuses on the latter: because the interest on reserves is the return on banks' alternative to lending, a narrowing of the spread raises the opportunity cost of lending and can discourage it. This channel can rationalise the empirical findings, but the reduced-form evidence cannot distinguish it from other mechanisms that could generate the same observations. We now consider those alternatives and evaluate cross-sectional evidence that separates them.

2.2 Competing explanations and cross-sectional evidence

The comovement in Table 1 is consistent with the mechanism developed in this paper but does not by itself identify it. Following the GFC, the interbank rate fell towards the floor over a period of weak loan demand, interbank fragmentation, and strained bank balance sheets, and one in which the ECB eased in response to those conditions. The market rate compressing towards the floor, abundant reserves, and weak lending may therefore be joint symptoms of that environment rather than evidence that a narrowing spread reduced credit supply, since these conditions are only partially absorbed by the aggregate controls.

Reversal-rate and sticky-deposit models provide a further explanation, under which a lower market rate reduces lending by compressing banks' margins against a floored deposit rate rather than by raising the return on reserves (Drechsler et al., 2017; Abadi et al., 2023; Eggertsson et al., 2024).

The reserve reallocation points towards the opportunity-cost channel. With ample reserves, the return on the outside option to lending is the rate on reserves, so a spread compressing towards the floor raises the cost of lending relative to holding reserves, and the shift into central-bank balances is the reallocation our mechanism predicts. While this result supports the proposed mechanism, it does not rule out the sticky-deposit channel. To separate the two, and to distinguish the mechanism from weak demand, fragmentation, and bank stress, we exploit cross-sectional heterogeneity across banks, where time fixed effects absorb the common aggregate environment and identification comes from how banks with different exposure to the spread respond.

($p = 0.03$). See Appendix D.1.

	Bank + quarter FE	Core/periph. × quarter FE
	(1)	(2)
$s_t\times$ reserve-richness	0.018**	0.022***
	(0.007)	(0.008)
$s_t\times$ deposit funding	0.003	0.002
	(0.007)	(0.008)
$s_t\times$ capitalisation	0.003	−0.004
	(0.007)	(0.007)
Banks	62	62
Obs.	1,784	1,784

Notes: Top quartile of the asset distribution. The dependent variable is the log loan share, $\ln(L_{i,t}/A_{i,t})$. Characteristics are standardised and bank-constant. All columns include bank fixed effects; column 1 adds quarter fixed effects, column 2 core/periphery-by-quarter. Standard errors clustered by bank in parentheses. The periphery is Ireland, Italy, Portugal, Spain and Slovenia. The core is Austria, Belgium, France, Germany and the Netherlands. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 2: Cross-sectional heterogeneity in the loan share

We interact the aggregate spread with time-invariant bank characteristics: reserve-richness, which identifies the banks for which the return on reserves is the binding outside option, where our mechanism should operate most strongly, and deposit funding, which captures the sticky-deposit margin. A third interaction, with bank capitalisation, evaluates the role of bank stress. We estimate the specification:

$$\ln\left(L_{i,t}/A_{i,t}\right) = \alpha_i + \delta_t + \sum_k \theta_k \left(s_t \times Z_{k,i}\right) + u_{i,t}, \tag{2.2}$$

where $L_{i,t}/A_{i,t}$ is the loan share of assets, the natural margin for a reallocation between loans and reserves; α_i and δ_t are bank and quarter fixed effects; s_t is the spread to the floor; and the $Z_{k,i}$ are the standardised characteristics.[12] The bank effects absorb each characteristic's level and the quarter effects absorb all aggregate controls and anything else common across banks in a quarter, including the spread itself. θ_k is therefore identified only from the cross-section, measuring how banks of different types respond to the same spread. A positive θ_k marks a type that moves out of loans by more as the spread to the floor compresses.

Table 2 reports the interactions for the larger banks, the top quartile by assets, where the lending margin is most active.[13] For each 25 basis point compression of the spread, a bank one

[12] Specifically, each $Z_{k,i}$ is bank i's average ratio over 2008-2010, less the cross-bank mean and divided by the cross-bank standard deviation. Reserve-richness uses cash and balances at the central bank over total assets, deposit funding uses customer deposits over total assets, and capitalisation uses equity over total assets, all from SNL Financial Fundamentals.

[13] The top quartile captures around 94% of total assets in the sample. The reserve interaction is positive across the size distribution and significant through the upper quartile; the full set of size cuts is in Appendix D.2.

standard deviation more reserve-rich lowers its loan share by around 1.8 percent more than the average bank (column 1). The deposit-funding interaction is small and insignificant: reliance on deposit funding does not determine how lending responds to the spread to the floor. Bank capitalisation, included to test the role of stress, is likewise insignificant throughout. Consistent with our mechanism, the tightening concentrates in reserve-rich banks, not in the deposit-funded banks implicated by a sticky-deposit explanation or the weakly-capitalised banks implicated by a stress one.

The quarter effects absorb common loan demand but not interbank fragmentation, since the core and periphery moved along different paths through the sovereign crisis. Replacing them with core/periphery-by-quarter fixed effects, which absorb each region's own path, the reserve interaction does not weaken but strengthens (column 2). It is therefore identified within region and quarter and is not the core/periphery divergence.

With the aggregate environment and the core-periphery divergence both absorbed, the concentration of the credit tightening in reserve-rich banks is difficult to attribute to weak demand, sticky deposits, bank stress, or fragmentation. The next section develops a theoretical framework that can rationalise these facts through the lens of information frictions in bank lending. In this model, a quantitative easing programme that lowers the interbank rate operates through two competing channels: a standard expansionary channel, through lower bank funding costs, and a contractionary opportunity-cost channel, whereby a narrower spread to the floor disincentivises lending and can drive credit rationing.

3 A macroeconomic model of credit rationing

At the core of the model is a canonical New Keynesian (NK) closed economy model. The representative household chooses consumption, C_t, labour supply, H_t, and allocates savings across bank deposits, S_t, risk-free nominal bonds, B_t, and firm equity, E_t, to maximise expected lifetime utility $\mathbb{E}_t \sum_{s=0}^{\infty} \beta^s U(C_{t+s}, H_{t+s})$. The consumption-savings decision yields the standard Euler equation,

$$1 = \mathbb{E}_t \left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}} \right] R_t, \tag{3.1}$$

where $\Lambda_{t,t+1} = \beta U'(C_{t+1})/U'(C_t)$ is the stochastic discount factor, R_t is the gross nominal return on deposits, and the return on bonds $R_t^B = R_t$ in equilibrium. The labour supply condition equates the real wage with the marginal rate of substitution: $W_t/P_t = -U'(H_t)/U'(C_t)$. Equity purchases are characterised by a zero-arbitrage condition outlined below.

A wholesale goods sector combines labour and purchases capital to produce a homogeneous intermediate good. This good is then sold to a retail sector under perfect competition. The retailers differentiate the intermediate good, selling their output under monopolistic competition subject to the Calvo (1983) price-setting friction.

Following Swarbrick (2023), the wholesale goods sector is characterised by information frictions in firm investment. This builds on two key assumptions. The first is that all investment projects require a single unit of productive capital for which firms need to raise a fixed quantity of external finance. This assumption ensures that firms rely on outside funding, but by treating all investment opportunities as a fixed size, we capture the inability of small firms to diversify risk.

The second key assumption is that every period, each intermediate goods firm draws a project characterised by a production technology, productivity level and a risk profile. A proportion η of firms, denoted *corporates*, have a perfectly observable project and so are suitable for raising funds via a bond market. The remaining $1 - \eta$ firms have a privately observed project, a proportion λ of which have no idiosyncratic risk (*safe*), whereas the remaining $1 - \lambda$ have a risky project that will only succeed with probability p_t (*risky*).

Because all loans are the same size, in a decentralised bond market the interest rate would be the only screening device, and safe firms would be rationed whenever the rate exceeds their expected return. The information asymmetry gives rise to a banking sector that can outperform bond markets by screening borrowers.[14] Despite not modelling differences in firm size, the fixed size of investment and information asymmetry capture salient features of small business: having private information and being unable to diversify risk. For this reason, we refer to the non-corporates as small firms.

Before turning to the problem facing the borrowers and lenders in the economy, we first outline details about monetary policy. We will differ from the standard NK model by giving the

[14] Indeed, a major rationale for the existence of banks is to mitigate borrowers' financing frictions (see Flanagan, 2025).

central bank three instruments. The first is the standard tool: the main policy target rate, R_t^p, which the central bank charges for short-term liquidity operations. Second, the central bank can directly vary the amount of liquidity to influence the short-term market interest rate on household savings, R_t.[15] This can be targeted through private sector bond purchases, or direct liquidity provision to the bank sector.[16] The third instrument is the interest rates on standing deposit ($\underline{R}_t$) and lending ($\overline{R}_t$) facilities. Banks can hold excess reserve balances in the former and access additional liquidity as required via the latter.[17]

3.1 Banks

Bank assets consist of business loans and central bank reserves, while liabilities include central bank liquidity and household deposits. The composition of the liability side is addressed below. We begin by examining the asset side. To extend finance to firms, the banks can post the terms of a menu of loans that borrowers can choose on application.[18] Loans are single-period, with terms specifying both an interest rate and an approval probability. This flexibility allows banks to offer multiple loan options at different interest rates to separate borrowers. These options are designed as incentive-compatible, or self-selecting, contracts. For instance, a risky firm might accept a higher interest rate if it increases the probability of approval compared to a lower-interest loan.

Specifically, the lenders post contracts $c_t^i = \{\tau_t^i, x_t^i\}$ for $i \in \{s, r\}$, where τ_t^i is the nominal repayment rate, and x_t^i the financing, or approval probability.[19] Letting R_t^i denote the gross nominal rate of return on capital for a type-i project and p_t the success probability of risky projects, lenders set contract terms subject to firms' individual rationality (IR) and incentive

[15]The first two instruments are implicitly the same, however to capture the policy tools used in practice, we model the implementation of the first via a Taylor rule, and the second to allow shifts of the market rate below the main policy rate towards the policy floor, $\underline{R}_t$.

[16]Either are equivalent as in equilibrium corporate bonds, household savings, and central bank loans to the banks will clear at the same interest rate.

[17]There is no regulatory reserve balance and so all bank reserve balances at the central bank are excess reserves.

[18]Because firm-type is drawn every period, it is not possible that banks learn the firm type over time and so credit terms are not a function of a firm's history.

[19]The contract does not include collateral. As shown by Bester (1985), lenders offering menus varying both interest rates and collateral can achieve separation when borrowers have sufficient collateralisable wealth. In Appendix E, we extend the bank problem to allow firms to pledge personal wealth $\bar{c}$ as collateral. The information rent is reduced by $(1-p_{t+1})\bar{c}$, shifting the threshold at which rationing occurs but preserving the mechanism: the rationing condition takes the same form as (4.4) with the information-rent term $(1-\lambda)(1-p_{t+1})R_{t+1}^s$ replaced by $(1-\lambda)(1-p_{t+1})(R_{t+1}^s - \bar{c})$. Full separation requires $\bar{c}$ large relative to the return on capital, a condition not satisfied for borrowers requiring external finance. Empirical evidence on the screening role of collateral is also mixed, with much of the literature finding that riskier borrowers post more collateral, consistent with loss mitigation rather than Bester-style screening (see Berger et al., 2016). Moreover, collateral effectiveness is weakest in the low-rate environments where the credit-rationing channel in this model is most relevant, since personal asset values are procyclical.

compatibility (IC) constraints. The relevant constraints can be written:

$$\mathbb{E}_t\left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}}\right]\tau_t^s \leq \mathbb{E}_t\left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}}R_{t+1}^s\right] \tag{3.2}$$

$$\mathbb{E}_t\left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}}p_{t+1}\right]\tau_t^r \leq \mathbb{E}_t\left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}}p_{t+1}R_{t+1}^r\right] - \mathbb{E}_t\left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}}p_{t+1}\left(R_{t+1}^r - \tau_t^s\right)\right]\frac{x_t^s}{x_t^r}. \tag{3.3}$$

The first constraint ensures the participation of safe firms by promising weakly positive surplus. The second provides an incentive for the risky firm to reveal their type, even choosing a higher interest rate loan. This is achieved through a higher probability of loan approval. When the lending contracts separate borrowers, therefore, safe loans have low repayment rates but a lower approval rate, while risky loans have a higher repayment rate but higher approval rate.[20]

Free entry of banks implies a zero-arbitrage condition. Banks enter, access liquidity at rate R_t via household deposits or central bank loans, and post loan contracts. Matching to firms is proportional to bank balance sheet size.[21] This matching assumption plays two roles: it pins down equilibrium intermediation through the free-entry condition, and it generates equilibrium excess reserves, making the interest on reserves the relevant opportunity cost of lending. The second property is essential for the competing channels of liquidity policy identified below; alternative reserve-demand motives such as liquidity risk or precautionary hoarding would deliver the same mechanism.

Denoting the volume of liquidity provision for bank j as S_t^j, the total volume of loans L_t^j, and the matched firms $f_t^j \equiv f_t S_t^j / \int S_t^j \mathrm{d}j$, the total *ex post* gross nominal rate of return to the representative bank is

$$\underline{R}_{t-1}\left(S_{t-1}^j - L_{t-1}^j\right) + \left[\lambda x_{t-1}^s \tau_{t-1}^s + (1-\lambda)\, x_{t-1}^r p_t \tau_{t-1}^r\right](1-\eta)\, f_{t-1}^j Q_{t-1}^K, \tag{3.4}$$

where $\underline{R}_{t-1}$ is the interest on reserves and $\left(S_{t-1}^j - L_{t-1}^j\right)$ the excess reserves of bank j.[22]

Each borrower will use the loan to purchase a single unit of capital at price Q_t^K. Therefore, total loans extended $L_t^j \equiv (1-\eta)\left(\lambda x_t^s + (1-\lambda)\, x_t^r\right) f_t^j Q_t^K$. Denoting the loan supply-demand ratio $\phi_t^j \equiv \frac{S_t^j}{(1-\eta) f_t^j Q_t^K}$, the zero-profit condition will determine the equilibrium volume of banking

[20] The implications of these contracts are discussed further in the next section.

[21] Match uncertainty would generate a role for the interbank market and is explored separately.

[22] If negative, the bank must use the lending facility at rate $\overline{R}_t$. Without liquidity risk, this never occurs in equilibrium (see Appendix C.1).

sector liquidity:

$$1 = \mathbb{E}_t \left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}} \left(\underline{R}_t + \left[\lambda x_t^s \left(\tau_t^s - \underline{R}_t \right) + (1-\lambda) x_t^r \left(p_{t+1} \tau_t^r - \underline{R}_t \right) \right] \frac{1}{\phi_t} \right) \right] \tag{3.5}$$

where we drop the bank index j since it follows that ϕ_t must be equal for all banks. Given that bank liabilities are risk-free deposits but assets are risky loans, it is possible for there to be *ex post* profits or losses in equilibrium. When there are profits, the household will receive a dividend, recapitalising the banks when there are losses.

Given their current level of liquidity, the banks choose the loan contract terms to maximise the expected next-period real surplus by solving:

$$\begin{aligned} \max_{c_t^s, c_t^r} \mathbb{E}_t & \left[\Lambda_{t,t+1} \left\{ \lambda x_t^s \left(\frac{\tau_t^s}{P_{t+1}} - \frac{\underline{R}_t}{P_{t+1}} \right) + (1-\lambda) x_t^r \left(p_{t+1} \frac{\tau_t^r}{P_{t+1}} - \frac{\underline{R}_t}{P_{t+1}} \right) \right\} \right] \\ \text{s.t.} \quad & 0 \leq x_t^s \leq x_t^r \leq 1 \\ & \lambda x_t^s + (1-\lambda) x_t^r \leq \phi_t \end{aligned} \tag{3.6}$$

and subject to constraints (3.2) and (3.3). The $x_t^r \geq x_t^s$ also follows from the IC constraints and the inequality constraint (3.6) is a liquidity constraint. ϕ_t is determined by (3.5) and is less than one when loan demand exceeds available liquidity. This is not a hard constraint since banks can always access additional funds, but additional liquidity comes at the policy ceiling rate $\overline{R}_t$, making it unprofitable. This implies the possibility of effective liquidity constraints depending on macro-financial conditions and the monetary policy stance.

When constraint (3.6) is slack, then there is excess liquidity in the banking sector, banks hold excess reserves which are held in the central bank deposit facility. The solution to the bank's problem gives

$$\mathbb{E}_t \left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}} \left(p_{t+1} R_{t+1}^r - \underline{R}_t \right) \right] = \varrho_t - \psi_t \frac{1}{1-\lambda} + \varphi_t^r \frac{1}{1-\lambda} \tag{3.7}$$

$$\mathbb{E}_t \left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}} \left(\left(\lambda + (1-\lambda) p_{t+1} \right) R_{t+1}^s - \underline{R}_t \right) \right] = \varrho_t + \varphi_t^r - \varphi_t^s, \tag{3.8}$$

where ϱ_t is the Lagrange multiplier on the feasibility constraint, φ_t^s and φ_t^r those on x_t^s and $1 - x_t^r$ respectively, and ψ_t is the Lagrange multiplier on $x_t^r - x_t^s$. These first-order conditions are also subject to complementary slackness conditions that include zero-lower bounds on the four Lagrange multipliers:

$$\varphi_t^s, \varphi_t^r, \varrho_t, \psi_t \geq 0. \tag{3.9}$$

3.2 Intermediate goods firms

Intermediate goods firms draw their project type at the end of period t and seek external finance. If they draw an observable project, then they are characterised as a *corporate* and access funds in the bond market. Otherwise, as a *small firm*, they must apply for a bank loan. They may or may not be successful in securing funds; if firms are successful, they purchase the required unit of capital at nominal price Q_t^K, ready for production in the following period, otherwise, they must exit. New firms can enter but must pay fixed entry costs.

Of the funded risky projects, a proportion $1-p_{t+1}$ will fail in the next period before production begins, with all capital lost. Success probability, $p_{t+1} \in [0,1]$, is subject to aggregate risk. After production, the firm repays the loan, sells the depreciated capital back to the capital market at Q_{t+1}^K, and returns any surplus to the household.

We denote corporates, safe- and risky-project firms with superscript $i \in \{c, s, r\}$. A successfully funded project requires a single unit of capital that is converted into ω_t^i productive units where $\omega_t^r = 1/p_t > \omega_t^c = \omega_t^s = 1$.[23] The firm hires $h_t\left(\omega_t^i\right)$ units of labour and produces output using constant returns to scale technology,

$$y_t\left(\omega_t^i\right) = z_t\left[\omega_t^i\right]^{\alpha}\left[h_t\left(\omega_t^i\right)\right]^{1-\alpha}, \tag{3.10}$$

where aggregate total-factor productivity, z_t, follows a stationary stochastic process. Capital depreciates at rate δ, so the remaining capital after production will be $\omega_t^i(1-\delta)$. Denoting the final consumption good price P_t, the nominal market value of capital Q_t^K, and the wholesale good price P_t^W, we can write the real value of a successfully funded type-i firm as:

$$V_t^i = \max_{h_t\left(\omega_t^i\right)}\left\{\frac{P_t^W}{P_t}y_t\left(\omega_t^i\right) - \frac{W_t}{P_t}h_t\left(\omega_t^i\right) - \left(\tau_t^i\frac{Q_{t-1}^K}{P_t} - (1-\delta)\,\omega_t^i\frac{Q_t^K}{P_t}\right) + \overline{V_t}\right\}, \tag{3.11}$$

where τ_t^i is the aggregate-state indexed loan repayment rate and $\overline{V_t}$ represents the *ex-ante*, real

[23] The assumption that $\omega_t^r = 1/p_t$ is not required but allows us to isolate the effects of risk.

continuation value of a firm, prior to drawing its type, given by:

$$\overline{V_t} \equiv \mathbb{E}_t \left[\Lambda_{t,t+1} \left(\eta V_{t+1}^c + (1-\eta) \left(\lambda x_t^s V_{t+1}^s + (1-\lambda) x_t^r p_{t+1} V_{t+1}^r \right) \right) \right], \tag{3.12}$$

which is a probability-weighted average of future values conditional on the next period project draw. The solution to (3.11) yields the standard labour demand condition equating the real wage with the marginal product of labour. Since output per worker and the efficiency capital-labour ratio are equal across firm types, we can write the gross nominal return on capital as

$$R_t^i \equiv \frac{\alpha \frac{P_t^W}{P_t} y_t^i + (1-\delta) q_t^K \omega_t^i}{q_{t-1}^K} \Pi_{t-1,t}, \tag{3.13}$$

where $q_t^K \equiv Q_t^K / P_t$ is the real price of capital. Noting that the gross return on efficiency units of capital, $\alpha \frac{y_t(\omega_t^i)}{\omega_t^i} + (1-\delta)$, is equal for all firms, it follows that $R_t^r = \omega_t^r R_t^c = \omega_t^r R_t^s$.

3.2.1 Firm entry

Firms can earn positive profits due to the information asymmetry and because each firm is a fixed size, the number of firms in the economy will matter for aggregate outcomes. To model firm dynamics, we assume firms pay a small fixed cost equal to F units of the final good to enter. The entry cost is a fee paid to households (a rebate), so it does not absorb real resources and enters household income as a lump-sum transfer.

To pay the entry costs, firms sell equity to households at nominal price Q_t^E. Total equity purchases, E_t, corresponds to the number of new firms invested in, where each share is a claim on the future profit streams of an entering firm.

$$E_t = \left(f_t - \left(\eta + (1-\eta) \left(\lambda x_{t-1}^s + (1-\lambda) x_{t-1}^r \right) \right) f_{t-1} \right).$$

Under this assumption, new firms will enter until the expected discounted profits $\overline{V}_t$, given by equation (3.12), equals the entry cost F.

3.3 Retailers and capital good producers

Firms in the retail sector differentiate a homogeneous intermediate good purchased at price P_t^W into final retail goods which are sold under monopolistic competition subject to a Calvo friction, whereby they face a fixed probability, ξ of being able to update each period. This leads to the usual conditions for the optimal price for price setters, P_t^*, and law of motion for inflation $\Pi_{t-1,t} \equiv P_t/P_{t-1}$, which are characterised by the usual NK Phillips curve.[24]

We also introduce capital producers that invest in new capital and buy and sell in a market for capital goods at the end of the period. Firms that secure funding seek to purchase enough capital to make up the required amount and exiting firms sell their remaining capital stock. Subject to the demand for capital and the market price, Q_t^K, capital producers purchase final retail goods, converting them into new capital goods to sell to firms under perfect competition. We assume that it is costly to adjust investment plans following Christiano et al. (2005). Because $\omega_t^r = 1/p_t$ and $\omega_t^c = \omega_t^s = 1$, in aggregate, the total units of capital sold is equal to the efficiency units in production, and therefore the aggregate capital stock evolves according to:

$$K_t = (1-\delta)K_{t-1} + I_t \left[1 - \frac{\phi_K}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right]. \tag{3.14}$$

3.4 Market clearing and aggregation

Labour market clearing implies that total labour demanded by the three types of firm will equal the labour supplied by households, H_t. The perfect labour market implies that all firms will choose the same efficiency-capital-labour ratio and so, giving the capital markets clearing condition as

$$K_t \equiv \left[\eta + (1-\eta)\left(\lambda x_t^s + (1-\lambda)\, x_t^r\right)\right] f_t, \tag{3.15}$$

we can write the aggregate labour demand and intermediate good production function as

$$\frac{W_t}{P_t} = (1-\alpha)\, MC_t z_t \left(\frac{K_{t-1}}{H_t}\right)^\alpha$$
$$Y_t^W \equiv \int_i y_t^i \mathrm{d}i = z_t K_{t-1}^\alpha H_t^{1-\alpha}$$

where $MC_t \equiv P_t^W/P_t$ is the real marginal cost in the retail sector. Finally, the goods market clears, implying the aggregate resource constraint $Y_t = C_t + I_t$ where $Y_t = Y_t^W/\Delta_t$, and Δ_t is a measure of price dispersion.

[24]See Appendix A for equilibrium conditions.

3.5 Monetary policy

Unlike the standard New Keynesian economy, the volume of liquidity in circulation affects the market interest rate through bank balance sheet and profitability constraints. When the central bank purchases corporate bonds, it replaces higher-return assets with lower-return reserves on bank balance sheets; the bond market then only clears at a lower interest rate.[25] The central bank can therefore target the short-term market rate, R_t, through open market operations.

To distinguish between the central bank interest rates, we assume that the main policy interest rate is set to satisfy a Taylor-type rule:

$$\log\left(R_t^p\right) = \log\left(\frac{\Pi}{\beta}\right) + \gamma_\pi\left(\pi_{t-1,t} - \pi^*\right) + \gamma_y\left(y_t - y^*\right) \tag{3.16}$$

where $\pi_{t-1,t} \equiv \log\left(\Pi_{t-1,t}\right)$ and $y_t \equiv \log\left(Y_t\right)$. In addition to the main policy rate, the central bank has two further tools. The first is the interest rate on excess reserves, set equal to the main policy rate minus a desired corridor: $\underline{R}_t = R_t^p - c_t$. The second is liquidity operations that move the market rate below the main policy rate towards the floor. We characterise this departure as a quantitative easing policy: $R_t = R_t^p - q_t$. The spread between the market rate and the floor is then $R_t - \underline{R}_t = c_t - q_t$, equal to the corridor when liquidity is not eased $(q_t = 0)$ and compressing below it under quantitative easing.

4 Monetary Policy Transmission: Mechanisms and Quantitative Results

This section characterises how bank lending incentives depend jointly on macro-financial conditions and monetary policy. These incentives give rise to three equilibrium lending regimes, distinguished by whether banks finance all loan applications, face binding liquidity constraints, or actively ration credit.

A key implication is that liquidity policies operate through two competing channels: a standard expansionary demand channel and a contractionary credit-rationing channel that works through banks' lending incentives. These map to the funding-cost and opportunity-cost channels of Section 2, now in general equilibrium. Which channel dominates depends on risk and profitability

[25] Equivalently, the central bank can provide liquidity directly via refinancing operations. In equilibrium, the interest on central bank loans equals the rate on corporate bonds and household savings.

conditions, and policy can shift the economy across regimes.

We first characterise equilibrium loan contracts and identify the three regimes. We then illustrate the steady-state thresholds using comparative statics, and finally quantify the competing channels using impulse responses simulations.

4.1 Loan contracts and equilibrium regimes

The bank first-order conditions (3.7) and (3.8) together with the (binding) IC and IR constraints, (3.3) and (3.2) imply a menu of loan contract specifying the loan repayment, τ_t^i, and loan approval probability, x_t^i.

Proposition 1 *If* $x_t^s > 0$ *(*$\varphi_t^s = 0$*) then* $x_t^r = 1$ *(*$\varphi_t^r > 0$*) in equilibrium.*[26]

Unless there is full rationing of safe firms, the approval rating on risky loans is 1 and all risky firms are funded. It follows that when banks wish to tighten lending standards due to changing macro-financial conditions, increased default risk for instance, they do so on price on risky loans and approval probability on safe loans.[27] Credit rationing therefore occurs on safe loans (good types) rather than risky loans (bad types), as the cost of separating the types rather than the untargeted rationing of Stiglitz and Weiss (1981).[28]

The bank first-order conditions, together with the firm and bank entry conditions, determine the equilibrium level of bank sector liquidity and potential mismatch in loan supply and demand. Despite coming at a cost of lowering bank profitability, surplus liquidity can routinely arise in equilibrium and banks can hold excess reserves. This stems from a free entry condition in the banking sector. Providing liquidity has positive expected value, more will be demanded until the zero-profit condition holds. The opportunity cost of funds is equal to the interest on reserves $\underline{R}_t$.

While the banking sector can hold excess liquidity and provide enough loans to fulfil all firm financing needs, there are two other possible equilibrium outcomes. Either banks can become liquidity constrained when the marginal cost of funds exceeds the marginal return on lending, or

[26] All proofs in Appendix C.

[27] This is consistent with evidence presented in Swarbrick (2023). Probit regressions using UK SME lending data reveal that low and average risk loans experienced lower approval rates during periods of credit tightening, whereas above average risk loans did not.

[28] In Stiglitz and Weiss (1981) the bank cannot sort applicants and denies a subset at the bank-optimal rate, with the safe borrowers priced out rather than separated. Here the menu separates the types, the approval probability taking the screening role that collateral takes in Bester (1985), which our firms lack the wealth to post (footnote 19).

banks can ration credit when the marginal information rent to risky firms exceeds the marginal revenue from safe loans.

Proposition 2 *There is no credit rationing in equilibrium if*

$$\mathbb{E}_t\left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}}\left(\lambda\left(R^s_{t+1}-\underline{R}_t\right)-(1-\lambda)\left(1-p_{t+1}\right)R^s_{t+1}\right)\right]>0 \tag{4.1}$$

Using this threshold, we can identify three distinct regimes:

1. ***Abundant liquidity**: there is full approval under a pooling equilibrium ($\tau^s_t=\tau^r_t$ and $x^s_t=x^r_t=1$) in which all firm financing needs are met if 4.1 is satisfied and:*

$$\mathbb{E}_t\left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}}\left[1-(1-\lambda)\left(1-p_{t+1}\right)\right]R^s_{t+1}\right]\geq 1 \tag{4.2}$$

2. ***Scarce liquidity**: there is restricted lending due to binding liquidity constraints under a separating equilibrium ($\tau^s_t<\tau^r_t$ and $x^s_t<x^r_t=1$) in which not all firms are financed if 4.1 is satisfied and:*

$$\mathbb{E}_t\left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}}\left[1-(1-\lambda)\left(1-p_{t+1}\right)\right]R^s_{t+1}\right]<1 \tag{4.3}$$

3. ***Credit rationing**: there is restricted lending due to credit rationing if*

$$\mathbb{E}_t\left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}}\left(\lambda\left(R^s_{t+1}-\underline{R}_t\right)-(1-\lambda)\left(1-p_{t+1}\right)R^s_{t+1}\right)\right]=0 \tag{4.4}$$

Corollary 1 *The incentive to ration credit rises in: the share of risky firms, $1-\lambda$; the interest rate on reserves, $\underline{R}_t$; and the expected risky firm default rate, $1-p_t$. Given policy rates, the credit rationing incentive always falls in the return on capital, R^s_{t+1}, if $\lambda>(1-\lambda)(1-p_t)$.*[29]

Corollary 2 *Under non-rationing, the likelihood of liquidity constraints binding rises in the expected risky firm default rate, $1-p_t$, and the firm share of risky firms, $1-\lambda$*

To interpret the rationing condition (4.4), first note that from IC constraint (3.3), the informa-

[29] This holds if the number of safe firms in the economy outnumber the number defaulting risky firms. This condition will be satisfied under any reasonable calibration.

tion rent earned by risky firms is

$$\mathbb{E}_t \left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}} (1 - p_{t+1}) R^s_{t+1} \right] x^s_t, \tag{4.5}$$

which increases in the number of safe loans made. Condition (4.4) equates the marginal revenue from issuing a safe loan, $\lambda \left(R^s_{t+1} - \underline{R}_t \right)$, with the marginal cost from the resulting increase in the information rent. Once this cost outweighs the revenue, due to high default risk or a high return on reserves, banks ration credit until the two are equal. The interest on reserves therefore determines the opportunity cost of lending: as it rises, the incentive to ration credit increases and bank holdings of excess reserves rise.

Two features of this mechanism are worth noting. First, credit rationing is a profit-maximising response, not a consequence of insufficient funding. Banks can always expand their balance sheets by accessing additional liquidity; lending is tightened because the return on reserves rises relative to the return on lending. Second, "scarce liquidity" in the model is scarcity for the real economy, not for banks. When lending margins are compressed, banks optimally reallocate towards reserves: aggregate bank liquidity may increase even as the volume of credit extended to firms declines.[30]

4.2 Comparative statics

Figure 2 provides a steady-state illustration of the lending regimes characterised in Proposition 2. It shows how equilibrium outcomes vary with borrower risk and the width of the policy corridor, defined as the spread between the main policy rate and the interest on reserves. Movements along either dimension shift banks' lending incentives by altering the profitability of extending loans relative to holding reserves, generating transitions between abundant liquidity, scarce liquidity, and credit rationing.

In addition to borrower risk and the policy corridor, the three regions depend only on a small set of structural parameters. The composition of small firms between safe and risky types, $1-\lambda$, is central: a higher share of risky firms worsens adverse selection and increases the likelihood of credit rationing. The remaining parameters are the discount factor, β, and firm entry costs,

[30]This departs from the standard banks-as-intermediaries view. A reduction in lending does not translate one-for-one into an increase in reserves: because reserves yield a lower return than loans, substituting away from lending reduces bank profitability and limits balance-sheet expansion. Separately, excess reserves can also arise in low-risk environments when low firm profitability discourages entry, reducing aggregate loan demand below available bank liquidity. In this case, excess liquidity reflects weak loan demand rather than impaired loan supply.

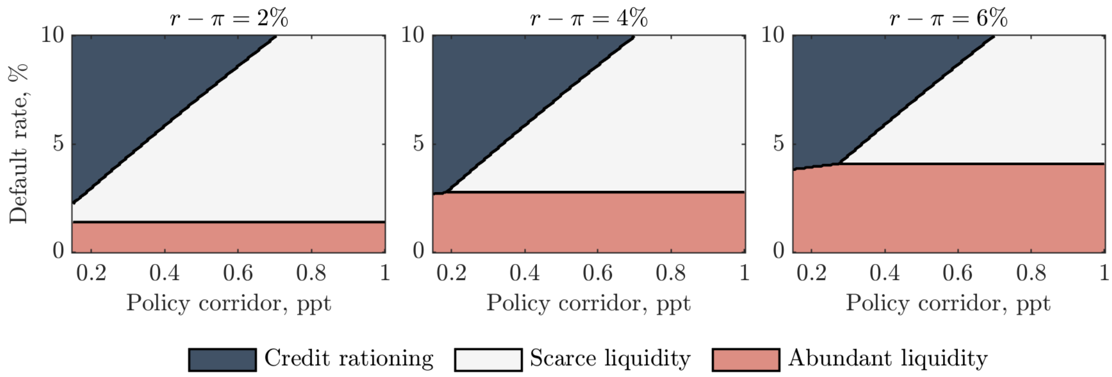

Figure 2: Comparative statics showing the role of risk (risky firm default rate), the policy corridor and the steady-state real interest rate. Other parameter values: $\eta = 0.5$, $\lambda = 0.775$, $F = 0.15$, $\beta = 0.9951, 0.9902, 0.9855$.

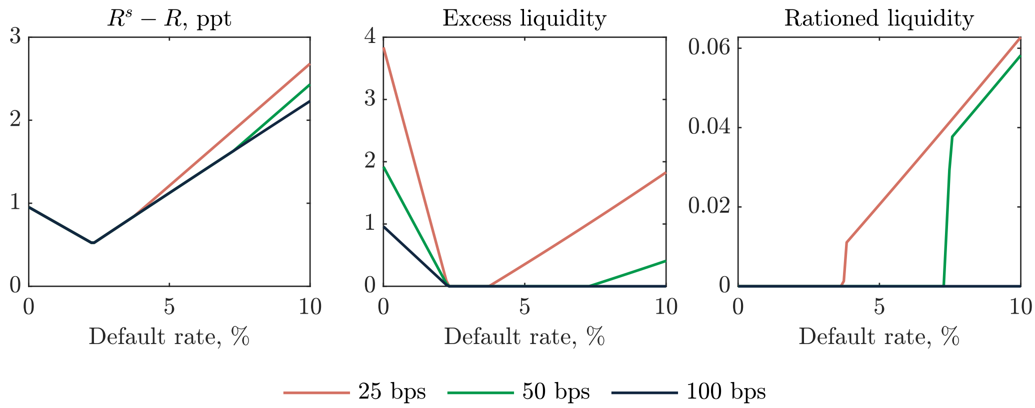

Figure 3: Comparative statics showing the role of risk (risky firm default rate) and the policy corridor on key macro-financial outcomes. Parameter values: $\eta = 0.5$, $\lambda = 0.775$, $F = 0.15$, $\beta = 0.992$.

F, both of which govern the demand for credit. As illustrated across the panels of figure 2, higher β (or lower F) raises the present value of future firm profits, encouraging entry and increasing loan demand. This makes binding liquidity constraints and credit rationing more likely, shrinking the region in which a pooling equilibrium with abundant liquidity emerges.[31]

Figure 3 illustrates how the regimes map into macro-financial outcomes. Although average loan approval rates are lower when liquidity is scarce than when abundant, macroeconomic performance need not be worse: in the abundant liquidity region, weak firm profitability and subdued entry can generate lower steady-state output and a larger credit wedge, defined as the spread between the return on capital and the risk-free rate, despite full loan approval. The credit wedge is minimised at the boundary where condition (4.1) is satisfied and the pooling condition (4.2) binds.

[31]Secular declines in real interest rates therefore influence steady-state lending conditions, not only through standard intertemporal substitution, but also by affecting firm entry. When risk is high and lending conditions already tight, lower real rates can tighten effective liquidity constraints.

Monetary policy plays an asymmetric role across these margins. By lowering the policy floor, policymakers can directly shift the credit rationing threshold outward, as shown in figure 3. However, steady-state liquidity constraints are determined by secular factors, including the natural rate of interest and firm entry costs, and cannot be eliminated through interest rate policy alone.

4.3 Liquidity policies: two competing channels

We now study the transmission of liquidity policies in the presence of the three lending regimes. We model a quantitative easing (QE) programme as an open-market operation that increases reserve balances and pushes the overnight market rate R_t below the main policy rate R_t^p, towards the policy floor $\underline{R}_t$.[32] In the baseline simulations, the policy is implemented as an unexpected, temporary reduction in R_t of 25 basis points (annualised), corresponding to a move halfway from the policy rate to the floor, and following an AR(1) process with persistence of 0.75.[33] Although this resembles a conventional rate cut from the perspective of households, because it lowers the market interest rate, it also alters banks' incentives by compressing the spread between the return on lending and the interest on reserves.

In the model, QE therefore operates through two competing channels. The first is the standard *expansionary* demand channel: a fall in R_t raises consumption and increases the incentive to invest. The second is a *contractionary* credit-rationing channel: by moving R_t closer to $\underline{R}_t$, the policy increases the opportunity cost of funding loans (relative to holding reserves), lowering banks' lending incentives and worsening the adverse-selection friction. When this channel dominates, banks ration credit, optimally reducing approval rates for safe loans. This causes credit spreads to rise, and investment falls even though household demand strengthens.

To evaluate the dynamic implications of the policy, we simulate the model using the King, Plosser and Rebelo (1988, KPR) class of utility with external habits in consumption and a standard New Keynesian calibration.[34] For the new parameters, we set $\eta = 0.5$ so half of firms are corporates, $\lambda = 0.775$, $F = 0.15$, and unless otherwise stated, a steady-state annual risky firm default rate of 6% ($\bar{p} = 0.985$). We focus on the role of borrower risk and the size of the

[32] This pattern is consistent with the empirical response of short-term market rates to asset purchase programmes; see Figure 1. The model captures this short-rate and reserve-side channel of purchases, abstracting from the duration and portfolio-balance effects on long-term yields.

[33] The adjustment in R_t stands in for the purchase quantity that would deliver it through the balance-sheet channel outlined in Section 3.5.

[34] Full details of the calibration are shown in Table 3 in Appendix A.

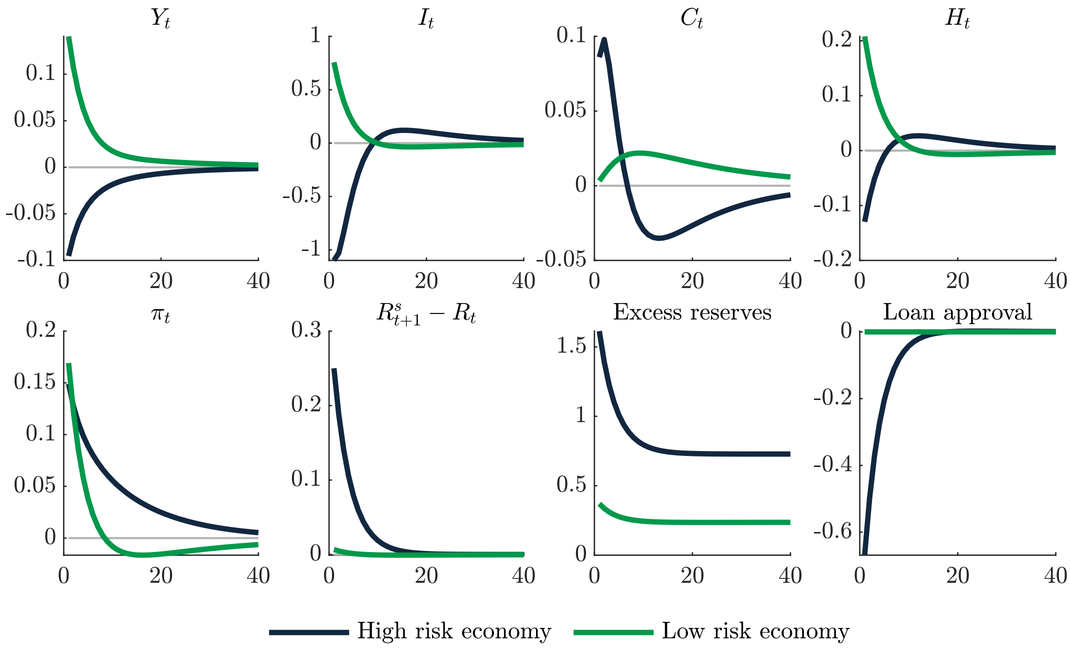

Figure 4: Impulse response functions to an unexpected temporary 'QE' programme. Plots in the top row show % deviation from steady state. The bottom row shows ppt deviation except for excess reserves with plots the level response. Excess reserves is given as the ratio of reserves to stock of loans. Per annum risky firm default rate is 12% (high risk) and 2% (low risk).

liquidity programme, since these determine whether the economy remains in the non-rationing region or crosses into the rationing regime.

Figure 4 compares impulse responses to the same QE shock in two economies that differ only in steady-state borrower risk. In the low-risk economy, the programme behaves like a conventional expansionary monetary policy shock. A lower R_t raises aggregate demand through the usual intertemporal-substitution channel, increasing consumption and investment. Lending standards remain unchanged because the economy stays away from the rationing threshold, so the demand channel dominates.[35]

In the high-risk economy, the same policy produces the opposite short-run output response. Because banks are already within the rationing threshold (4.1), compressing the spread between R_t and $\underline{R}_t$ strengthens the incentive to hold reserves rather than expand lending. Banks tighten lending standards by reducing safe-loan approval, credit spreads rise, and investment contracts. Reserves increase sharply, reflecting the endogenous reallocation of bank balance sheets towards low-return liquid assets. The economy therefore displays strongly state-dependent transmission:

[35] A subtle point is that while the compressed spread moves the economy closer to the credit-rationing threshold, it simultaneously moves it away from the scarce-liquidity region. Reserves therefore rise endogenously as lending expands, reflecting higher bank liquidity rather than tighter lending incentives. This distinction underscores that liquidity scarcity in the model is driven by lending profitability rather than by funding availability.

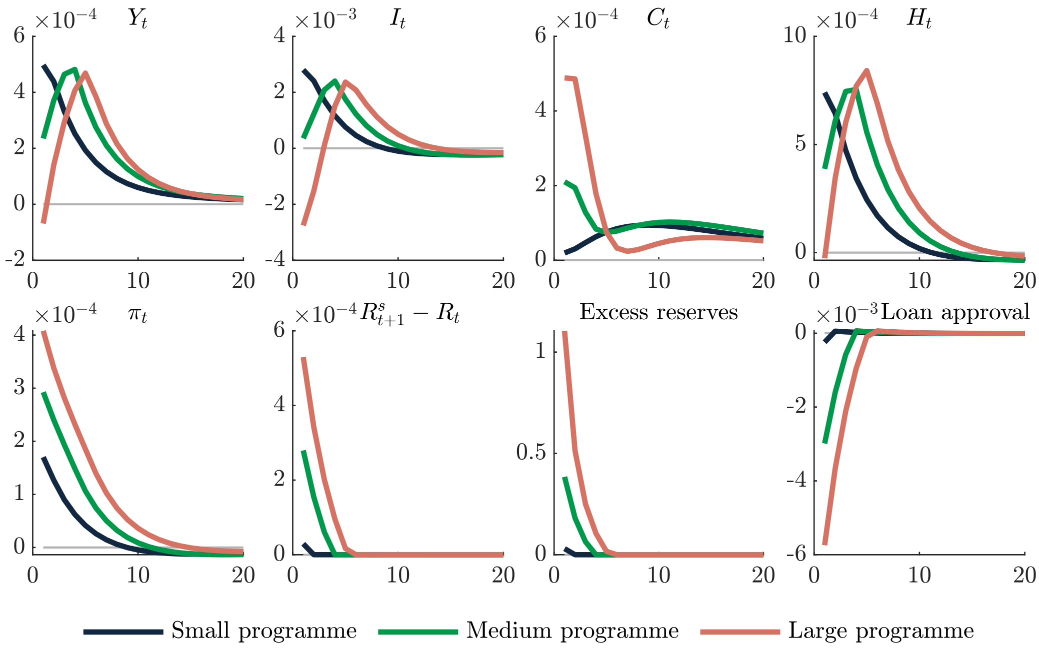

Figure 5: Impulse response functions to a temporary 'QE' programme. Plots in the top row show % deviation from steady state. The bottom row shows ppt deviation except for excess reserves which plots the ratio of reserves to stock of loans.

the same liquidity operation is expansionary when risk is low, but can be contractionary when risk is high because it pushes lending incentives into the rationing regime.

Figure 5 illustrates the same mechanism by varying the size of the QE programme. Small programmes leave the economy in the non-rationing region, so responses scale approximately proportionally with shock size. Larger programmes, however, move R_t sufficiently close to $\underline{R}_t$ that condition (4.1) binds, triggering a regime shift: loan approval falls, spreads rise endogenously, and output can contract on impact despite higher consumption demand. Programme size therefore matters nonlinearly.

4.4 Robustness: investment adjustment costs and preferences

We assess robustness along two dimensions: the presence of investment adjustment costs and alternative preference specifications that alter labour supply and consumption responses. Liquidity policies affect the real economy through an expansionary demand channel and a contractionary credit-rationing channel that operates through investment. Introducing investment adjustment costs dampens the responsiveness of investment to changes in lending conditions. As a result, the contractionary credit-rationing channel is weakened, allowing the expansionary demand channel to dominate even in high-risk economies.[36]

Another margin is the strength of the wealth effect on labour supply. Adopting preferences of the type proposed by Jaimovich and Rebelo (2009, JR), which allow for a weak short-run wealth effect on labour supply, can substantially dampen the consumption response to lower interest rates. As a result, the expansionary demand channel is weakened. In this case, liquidity programmes can generate much larger and more persistent contractions in output, as the decline in investment driven by credit rationing is no longer offset by higher consumption.[37]

Finally, combining JR preferences with investment adjustment costs reverses this result. Adjustment costs limit the contractionary investment response induced by tighter lending standards, while the weak wealth effect prevents excessive labour supply responses. Together, these forces restore the dominance of the demand channel, so that even large liquidity programmes generate positive output responses despite increased credit rationing.[38]

4.5 Liquidity policies at the effective lower bound

In practice, liquidity policies are most often used when the main policy interest rate, R_t^p, is constrained by the effective lower bound (ELB). This raises the question of how the ELB alters the balance between the expansionary demand channel and the contractionary credit-rationing channel. The key mechanism in this environment is the response of inflation expectations.

Figure 6 plots impulse response functions to a negative demand shock, with and without a QE response, in an economy with investment adjustment costs.[39] The demand shock is modelled as an unexpected increase in the household discount factor, followed by its gradual return to steady state.[40]

The shock pushes the policy rate to the ELB, where it remains for several periods. In the

[36]This mechanism is illustrated in Figure 7 in Appendix F, which shows that with adjustment costs, the same QE programme generates a positive output response despite tighter lending standards.

[37]See Figure 8 in Appendix F. Working in the same direction, increasing the degree of habit formation with the original KPR preferences will also dampen the offsetting effects of consumption demand. However, quantitatively, the effect is insufficiently strong to alter the key results.

[38]See Figure 9 in Appendix F. The balance between these forces is parameter-dependent: estimated DSGE models typically feature substantial investment adjustment costs (e.g. Smets and Wouters, 2003, 2007), which favour the demand channel, but estimated short-run wealth effects on labour supply tend to be small (e.g. Galí et al., 2012; Schmitt-Grohé and Uribe, 2012), which favours the credit-rationing channel. The credit-rationing channel operates and worsens lending conditions regardless of the specification.

[39]Investment adjustment costs are included to ensure that the shock generates a contraction in aggregate demand. Without adjustment costs, households would substitute away from consumption towards investment and labour, partially offsetting the decline in demand.

[40]The shock increases β by 0.01, and follows an AR(1) process with persistence 0.9.

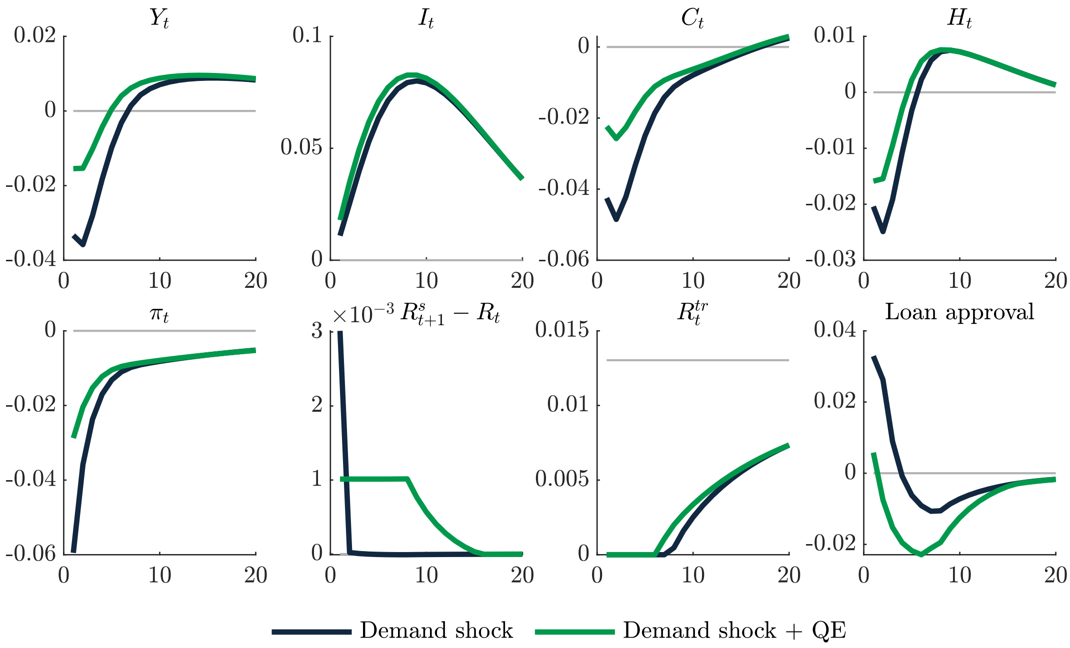

Figure 6: Impulse response functions to a demand shock with and without a 'QE' response and an economy with investment adjustment costs ($\phi_K = 4$). Plots in the top row show % deviation from steady state. The bottom row shows ppt deviation except for excess reserves which plots the ratio of reserves to stock of loans.

absence of QE, the inability of monetary policy to offset the decline in demand leads to a sharp fall in inflation. Higher household saving increases bank liquidity and results in a temporary easing of lending standards, but this effect is insufficient to stabilise aggregate activity.

When QE is implemented alongside the demand shock, the central bank expands reserve balances, lowering the overnight market rate below the policy rate and all the way to the policy floor.[41] As in the previous section, this activates two competing channels: an expansionary demand channel and a contractionary credit-rationing channel. Crucially, however, both channels are inflationary.

As shown analytically in the next section, tighter lending conditions raise firms' marginal costs, introducing a cost-push effect. Even when credit standards tighten and investment is partially restrained, inflation expectations rise. At the ELB, this increase in expected inflation reduces real interest rates and brings forward policy lift-off, providing additional stimulus over the horizon of the shock. As a result, QE remains expansionary on net, despite a tightening in lending standards.

[41] As before, the policy is implemented as a direct reduction in the market interest rate, here falling by 50 basis points relative to the policy rate, with persistence 0.8.

5 Optimal monetary policy design

This section studies the implications of credit frictions for welfare and optimal monetary policy in a simplified environment. We derive the log-linear New Keynesian representation in which endogenous lending distortions enter as a credit wedge, and obtain the associated quadratic welfare loss function. Building on this structure, we study optimal monetary policy through targeting rules under discretion and commitment, and examine the role of liquidity policy when nominal interest rates are constrained by the effective lower bound. The analysis highlights how credit frictions act as endogenous cost-push shocks and alter the inflation–output trade-off faced by the central bank.

Our analysis differs from two strands of work on optimal policy with credit frictions. Where an endogenous spread acts as a cost-push distortion that policy accommodates (Cúrdia and Woodford, 2010, 2016; Carlstrom et al., 2010; De Fiore and Tristani, 2013), here we will find that easing is moderated by the incentive to ration. Where a second instrument is assigned to financial shocks and quantitative easing is generally expansionary (Sims et al., 2023; De Fiore and Tristani, 2019), here liquidity policy is regime-dependent and can be contractionary.

5.1 Restricted environment and the efficient allocation

Assumption 1 (Restricted version) *We consider a restricted version without physical capital and with a fixed number of firms, f. Firms require external finance to operate, but we abstract from entry dynamics in order to focus on the allocation and policy implications of credit distortions. Preferences are additive-separable in consumption and labour:*

$$U\left(C_t, H_t\right) = \ln\left(C_t\right) - \varphi_H \frac{H_t^{1+\varphi}}{1+\varphi} \tag{5.1}$$

Additionally, the following parameter restrictions are imposed: $\eta = \pi^* = 0$.[42]

The social planner's problem is to choose allocations C_t, H_t and A_t to maximise household utility $\sum_t \beta^t U\left(C_t, H_t\right)$ subject to the resource constraint $C_t = Y_t$ and technology $Y_t = A_t H_t^{1-\alpha}$, where $A_t = \exp\left(z_t\right)\left[f x_{t-1}\right]^{\alpha}$, and where $x_t \equiv \lambda x_t^s + (1-\lambda)\, x_t^r$ is the total share of projects that are funded.[43]

[42]The key mechanism, endogenous credit rationing driven by adverse selection and the opportunity cost of reserves, is preserved, and the credit wedge conditions inherit the same qualitative properties as the full model.

[43]Since there are many projects and each has the same expected return, a pool of risky projects has the same net present value as a pool of safe projects. Therefore, we do not discriminate and can focus only on x_t.

The solution to the social planner problem yields $x_t = 1$ and $U_{H,t}/U_{C,t} = -(1-\alpha)A_t H_t^{-\alpha}$. This is equal to a full-lending (first-best), flexible-price economy where labour subsidies are imposed to remove the steady-state distortion stemming from monopolistic competition. In the optimal policy exercises that follow, we include constant labour subsidies and lending subsidies to impose the efficient steady-state allocation.[44]

5.2 The New Keynesian model with a credit wedge

Taking a first-order approximation around the efficient allocation yields the New Keynesian IS relationship and Phillips curve:

$$\pi_t = \beta \mathbb{E}_t [\pi_{t+1}] + \kappa \tilde{y}_t - \kappa\alpha \ln(x_{t-1}) \tag{5.2}$$

$$\tilde{y}_t = \mathbb{E}_t [\tilde{y}_{t+1}] - (r_t - \mathbb{E}_t [\pi_{t+1}] - r_t^n) \tag{5.3}$$

where

$$r_t^n = \rho + \mathbb{E}_t [\Delta z_{t+1}], \qquad \kappa = \frac{(1-\xi)(1-\xi\beta)}{\xi} \frac{1+\varphi}{1-\alpha} \tag{5.4}$$

and $\tilde{y}_t$ is the efficient output gap, π_t the log of inflation, and r_t the log nominal market interest rate.[45]

The key innovation relative to the benchmark New Keynesian model (e.g. Clarida et al., 1999) is that the marginal cost depends endogenously on credit allocation. When lending is constrained, effective productivity falls, generating a cost-push term in the Phillips curve. This mechanism mirrors the regime structure analysed earlier. Liquidity constraints and credit rationing reduce the funded share of projects, generating a supply-side distortion that feeds directly into inflation dynamics.[46]

5.2.1 Two policy instruments and two channels

In the full model the policymaker controls the main policy rate r_t^p, the market rate r_t, and the interest on reserves $\underline{r}_t$. Since the main policy rate has no independent allocative role, in this

[44] Equilibrium conditions and details of the steady-state lending subsidy are provided in Appendix B.

[45] Further details in Appendix B.

[46] Since $\ln(x_{t-1}) \leq 0$, the credit wedge acts as a one-sided cost-push shock: it raises inflation when lending is constrained but never lowers it. In the stochastic equilibrium, this implies a positive unconditional mean of inflation relative to the standard New Keynesian model, even under optimal policy.

section the policymaker sets r_t directly, leaving two instruments, r_t and $\underline{r}_t$, with the spread to the floor $\nu_t \equiv r_t - \underline{r}_t$ coinciding with the corridor. These two instruments affect lending through distinct channels. The log-linearised bank first-order condition under rationing yields:[47]

$$\ln(x_t) = \Lambda_0 - \Lambda^D (r_t - \rho) + \Lambda^\nu \hat{\nu}_t + \Lambda_y \mathbb{E}_t [\tilde{y}_{t+1}] + \Lambda_\pi \mathbb{E}_t [\pi_{t+1}] + u_{r,t} \tag{5.5}$$

where $\hat{\nu}_t \equiv \nu_t - \nu$ denotes the deviation of the spread from steady state, $u_{r,t}$ collects exogenous shocks, and:

$$\Lambda^D \equiv \frac{1-\alpha}{1+\alpha\varphi} \frac{R^s}{R^s - 1}, \qquad \Lambda^\nu \equiv \frac{1-\alpha}{1+\alpha\varphi} \frac{\lambda \underline{R}}{(R^s - 1)[\lambda - (1-p)(1-\lambda)]}. \tag{5.6}$$

The spread ν_t enters the linearised system as a convenient summary of the floor rate's effect on lending incentives, consistent with the empirical evidence in Section 2, where conditioning on the market rate isolates the floor as the operative policy variable. The two coefficients capture the two competing channels of monetary policy on lending identified in Section 4.3. The demand channel, governed by $\Lambda^D > 0$, captures how a lower interest rate raises aggregate demand and the expected return on lending, increasing banks' willingness to lend. The credit-rationing channel, governed by $\Lambda^\nu > 0$, captures how a narrower spread to the floor increases the opportunity cost of lending, reducing banks' lending incentive.

Lending is determined by three inequality constraints corresponding to the regimes identified in Proposition 2:[48]

$$\ln(x_t) \leq \Lambda_0 - \Lambda^D(r_t - \rho) + \Lambda^\nu \hat{\nu}_t + \Lambda_y \mathbb{E}_t[\tilde{y}_{t+1}] + \Lambda_\pi \mathbb{E}_t[\pi_{t+1}] + u_{r,t} \qquad \text{(Rationing)} \tag{5.7}$$

$$\ln(x_t) \leq \Upsilon_0 - \Upsilon_r(r_t - \rho) + \Upsilon_y \mathbb{E}_t[\tilde{y}_{t+1}] + \Upsilon_\pi \mathbb{E}_t[\pi_{t+1}] + u_{l,t} \qquad \text{(Liquidity)} \tag{5.8}$$

$$\ln(x_t) \leq 0 \qquad \text{(Feasibility)} \tag{5.9}$$

Banks ration credit when (5.7) binds, lending is constrained by scarce liquidity when (5.8) binds, and there is full lending under abundant liquidity when only the feasibility constraint (5.9) binds.[49]

[47] In general, the condition for Λ^ν should also include the lending subsidy, however, in all reasonable parameterisations, a subsidy is not required for $x = 1$ and so we drop this here for brevity.

[48] See Appendix B for further details.

[49] The absence of $\hat{\nu}_t$ in (5.8) reflects the fact that when bank liquidity is scarce, there are no excess reserves and the interest on reserves is irrelevant to bank profitability. The spread instrument ν_t therefore affects only the rationing margin, consistent with Corollary 1.

Proposition 3 (No-ELB benchmark) *Away from the effective lower bound on the floor, the policymaker can always set ν_t sufficiently large to ensure that credit rationing does not occur. The spread instrument ν_t neutralises the credit-rationing channel, though lending may still be constrained by low bank profitability through the liquidity channel.*[50]

Proposition 3 establishes that the spread to the floor is sufficient to address credit rationing but not constrained lending more broadly. When $\underline{r}_t \geq \underline{r}^{ELB}$ binds, $\nu_t = r_t - \underline{r}^{ELB}$ and the spread is no longer a free instrument. The two channels become yoked: lowering r_t both stimulates demand and compresses ν_t, which can worsen banks' lending incentive. The credit wedge then depends on r_t through the net coefficient $\Lambda_r \equiv \Lambda^D - \Lambda^\nu$, which is positive at the efficient steady state, reflecting the local dominance of the demand channel. However, $\Lambda_r = 0$ at the boundary of the rationing regime (see Proposition 2) and is negative under credit rationing, where the credit-rationing channel dominates.[51]

5.3 Welfare loss function and optimal targeting rules

Taking a second-order approximation to household utility around the efficient undistorted steady state yields the loss function:[52]

$$\mathcal{L} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(-\lambda_x \frac{1-\alpha}{1+\varphi} \alpha \ln(x_{t-1}) + \frac{1}{2} \left[\pi_t^2 + \lambda_x \left(\tilde{y}_t - \alpha \ln(x_{t-1}) \right)^2 \right] \right) \tag{5.10}$$

where

$$\lambda_x = \frac{1+\varphi}{1-\alpha} \frac{(1-\beta\xi)(1-\xi)}{\zeta\xi} = \frac{\kappa}{\zeta} \tag{5.11}$$

Without the credit friction, $\ln(x_{t-1}) = 0$ and the loss function collapses to the standard case, which is linear-quadratic in inflation and the output gap. The possibility of credit rationing introduces additional sources of welfare loss.

First, reduced lending lowers effective productivity and output. This appears as a linear welfare loss through the term in $\ln(x_{t-1})$, capturing the direct cost of financing distortions. Second, there is a quadratic term in $\tilde{y}_t - \alpha \ln(x_{t-1})$, which is the gap between output and its natural

[50] All proofs in Appendix C.

[51] The linear approximation does not capture this reversal, which would require a global solution method. The qualitative insight that the ELB on the floor creates a policy-relevant interaction between the two channels is nonetheless robust.

[52] Further details in Appendix B.

(flex-price) level taking the credit allocation as given. To see this, note that real marginal cost can be written as

$$\widehat{mc}_t = \frac{1+\varphi}{1-\alpha}\left(\tilde{y}_t - \alpha \ln(x_{t-1})\right) \tag{5.12}$$

so that $\tilde{y}_t - \alpha \ln(x_{t-1}) = 0$ when prices are flexible. The welfare-relevant output gap therefore absorbs the credit wedge into the definition of potential output. Stabilising the marginal cost stabilises inflation, but under credit rationing this requires the policymaker to engineer an offsetting output gap since closing the gap to efficient output ($\tilde{y}_t = 0$) would leave marginal costs elevated, generating inflation. The loss function thus captures a trade-off between stabilising inflation and closing the efficient output gap that is absent under full lending.

5.4 Optimal policy under discretion

To evaluate optimal policy, we minimise period welfare loss subject to the Phillips curve (5.2), the credit wedge conditions (5.7)–(5.9), and the effective lower bound on the floor, $\underline{r}_t \geq \underline{r}^{ELB}$. When the floor is unconstrained, Proposition 3 establishes that the policymaker can independently prevent credit rationing by adjusting the spread ν_t. When the floor is constrained at the ELB, however, the policymaker must rely on liquidity operations that lower the market rate r_t below the main policy rate towards the floor.[53] In either case, lending may also be constrained by low bank profitability through the liquidity channel, which depends on lending returns rather than the spread and must be addressed through the market rate r_t directly.

Proposition 4 (No current rationing) *If credit is not rationed in period t (*$\ln(x_t) = 0$*), the discretionary targeting rule is:*

$$\pi_t = -\frac{\lambda_x}{\kappa}\left(\tilde{y}_t - \alpha \ln(x_{t-1})\right) \tag{5.13}$$

which reduces to the standard rule $\pi_t = -(\lambda_x/\kappa)\tilde{y}_t$ *when* $\ln(x_{t-1}) = 0$.

When past lending was constrained ($\ln(x_{t-1}) < 0$), the credit wedge enters the targeting rule as an endogenous cost-push shock through the marginal cost channel (5.12). The central bank must tolerate a larger negative output gap for a given inflation rate. Importantly, the targeting

[53] In the model, this is equivalent to choosing r_t directly, but these operations simultaneously compress ν_t, activating the credit-rationing channel. The optimal policy problem therefore requires balancing the demand benefits of liquidity provision against its effects on bank lending incentives.

rule itself is unaffected by whether the ELB currently binds: the policymaker uses conventional policy away from the ELB, or liquidity policies at the ELB, to satisfy (5.13).

Proposition 3 establishes that credit rationing will not occur when the floor is unconstrained. When the ELB is binding, however, the policymaker may be unable to prevent credit rationing. In this case, the policymaker faces a choice about the scale of liquidity provision, knowing that any reduction in r_t operates through both the expansionary demand channel and the contractionary credit-rationing channel identified in Section 4.3.

Proposition 5 (Credit rationing at the ELB) *When the ELB on the floor binds and credit is rationed (*$\ln(x_t) < 0$*), the discretionary targeting rule is:*

$$\pi_t = -\frac{\lambda_x}{\kappa}\left(\tilde{y}_t - \alpha \ln\left(x_{t-1}\right)\right) + \frac{\Lambda_r}{\kappa}\xi_{r,t} \tag{5.14}$$

where $\xi_{r,t} > 0$ *is the shadow value of relaxing the credit-rationing constraint, satisfying:*[54]

$$\xi_{r,t} = \beta\lambda_x \frac{1-\alpha}{1+\varphi}\alpha + \beta\alpha\mathbb{E}_t\left[\Lambda_r\xi_{r,t+1} + \Upsilon_r\xi_{l,t+1}\right] \tag{5.15}$$

The final term in (5.14) is an inflation bias whose sign is governed by Λ_r. Since Proposition 5 is conditioned on active credit rationing, and $\Lambda_r \leq 0$ in this region, the bias is negative: the policymaker restrains liquidity provision, accepting lower inflation and a wider output gap to limit the degree of credit rationing.

The multiplier $\xi_{r,t}$ captures the (discounted) marginal welfare gain from easing the credit constraint. The first term in (5.15) is the direct productivity benefit of additional lending. The remaining terms reflect how the expected future lending regime affects current policy through the expectations channel. The mechanism operates through the targeting rule (5.14): binding constraints in $t+1$ create inflation or deflation biases that feed back into current inflation expectations and the current output gap through the Phillips and IS curves.

Expected future rationing ($\xi_{r,t+1} > 0$) creates a future deflation bias (since $\Lambda_r \leq 0$), lowering $\mathbb{E}_t[\pi_{t+1}]$. Through the IS curve, lower expected inflation raises the real interest rate and depresses the current output gap; through the Phillips curve, it directly reduces current inflation.

[54]Equation (5.15) holds under active rationing. The general condition, which holds in all regimes, is $\xi_{r,t} + \xi_{l,t} + \xi_{x,t} = \beta\lambda_x \frac{1-\alpha}{1+\varphi}\alpha + \beta\alpha\mathbb{E}_t[\Lambda_r\xi_{r,t+1} + \Upsilon_r\xi_{l,t+1}]$, where $\xi_{l,t} \geq 0$ and $\xi_{x,t} \geq 0$ are the multipliers on the liquidity and feasibility constraints respectively.

Both effects worsen the current deflationary environment, leading the policymaker to ease more aggressively. This appears as an attenuated deflation bias (lower $\xi_{r,t}$). The deflation bias is therefore weakest when rationing is expected to persist.From (5.6), the severity of the bias increases with the degree of adverse selection; higher borrower risk or a larger share of risky firms raises $|\Lambda_r|$, sharpening the trade-off between demand stimulus and lending incentives. This is consistent with Figure 4, where liquidity policies become contractionary under high borrower risk.

Expected future constrained lending ($\xi_{l,t+1} > 0$) has the opposite effect. This regime occurs when bank profitability is low, causing reduced liquidity for lending and a negative expected $t+1$ output gap. In this case, the market rate, r_t, is the opportunity cost of funds rather than the interest on reserves. Since there is no credit rationing channel present, the policymaker can improve lending conditions through monetary accommodation, generating expected inflation to satisfy the targeting rule in Proposition 4. Expected future constrained lending ($\xi_{l,t+1} > 0$), therefore, generates an inflation bias (since $\Upsilon_r > 0$), raising $\mathbb{E}_t[\pi_{t+1}]$. Higher expected inflation lowers the real rate and stimulates the current output gap. Since expectations are already providing stimulus, the policymaker needs to ease less, strengthening the deflation bias (higher $\xi_{r,t}$). The deflation bias is therefore strongest when the policymaker expects the economy to transition from rationing to constrained lending.

5.5 Optimal policy under commitment

Under commitment from a timeless perspective, the policymaker internalises how current credit conditions affect future welfare through $\ln(x_{t-1})$ in the Phillips curve and loss function, and how promised future policy affects current lending incentives through $\mathbb{E}_t[\tilde{y}_{t+1}]$ and $\mathbb{E}_t[\pi_{t+1}]$ in the rationing condition (5.5).

Proposition 6 (Commitment targeting rule) *The commitment targeting rule is:*

$$\pi_t + \frac{\lambda_x}{\kappa}(\tilde{y}_t - \alpha \ln(x_{t-1})) = \mu_{\pi,t-1} + \frac{\Lambda_r}{\kappa}\xi_{r,t} + \frac{\Upsilon_r}{\kappa}\xi_{l,t} - \Omega_r \xi_{r,t-1} - \Omega_l \xi_{l,t-1} \tag{5.16}$$

where Ω_r, Ω_l are composite coefficients, and $\xi_{r,t}$, $\xi_{l,t}$ are the shadow values of the rationing and *liquidity constraints. Under credit rationing ($\xi_{r,t} > 0$, $\xi_{l,t} = 0$), the shadow value satisfies:*[55]

$$\xi_{r,t} = \frac{1}{\Gamma_r}\left[\beta\lambda_x \frac{1-\alpha}{1+\varphi}\alpha + \beta\alpha\mathbb{E}_t[\Lambda_r\xi_{r,t+1} + \Upsilon_r\xi_{l,t+1}]\right] \tag{5.17}$$

When $\ln(x_t) = 0$ and $\ln(x_{t-1}) = \xi_{r,t-1} = \xi_{l,t-1} = 0$, the rule reduces to the standard price-level targeting rule $\pi_t = -(\lambda_x/\kappa)(\tilde{y}_t - \tilde{y}_{t-1})$.

The commitment targeting rule (5.16) differs from the discretionary rule (5.14) in two respects. First, the lagged multipliers $\mu_{\pi,t-1}$, $\xi_{r,t-1}$, and $\xi_{l,t-1}$ introduce history dependence. The lagged NKPC multiplier $\mu_{\pi,t-1}$ generates the standard price-level targeting property. The terms in $\xi_{r,t-1}$ and $\xi_{l,t-1}$ propagate past lending constraints into current policy. Since $\Omega_r < 0$ under rationing,[56] past rationing ($\xi_{r,t-1} > 0$) raises inflation through $-\Omega_r\xi_{r,t-1} > 0$: the policymaker delivers accommodation that was committed to during the rationing episode in order to raise inflation expectations and ease the credit constraint at that time. It is the anticipation of this accommodation that reduces the severity of rationing under commitment relative to discretion.

Second, the shadow value $\xi_{r,t}$, which governs the deflation bias $(\Lambda_r/\kappa)\xi_{r,t}$, is amplified by $1/\Gamma_r > 1$ relative to discretion. The scaling arises because the commitment policymaker recognises that current rationing obliges future accommodation, making each unit of rationing more costly than under discretion. The deflation bias is therefore larger under commitment. More broadly, $1/\Gamma_r$ reflects a positive feedback loop: since $\Lambda_\pi, \Lambda_y > 0$, the promised future accommodation credibly raises $\mathbb{E}_t[\pi_{t+1}]$ and $\mathbb{E}_t[\tilde{y}_{t+1}]$, which raises the profitability of lending and relaxes the credit constraint for any given r_t. The amplification factor scales the entire recursion, including $\beta\alpha\mathbb{E}_t[\Lambda_r\xi_{r,t+1}]$: when future rationing is expected, the future deflation bias lowers expected inflation, reducing the effectiveness of this forward-guidance channel. The benefit of commitment is therefore largest when rationing is expected to be temporary and smallest when it is expected to persist.

Corollary 3 *The optimal degree of credit rationing under commitment is less severe than under discretion: $x_t^{\text{commit}} > x_t^{\text{discr}}$.*

This provides a new channel through which commitment matters at the ELB, beyond the standard real-rate channel. Forward guidance not only reduces real interest rates; it also directly

[55] Under discretion, $\Gamma_r = 1$. Under commitment, $\Gamma_r = 1 - \alpha(\Lambda_y - \Lambda_r) < 1$ since $\Lambda_y > \Lambda_r$. See the proof of Proposition 6.

[56] From the definition $\Omega_r \equiv [(1+\kappa)\Lambda_r - \Lambda_y - \kappa\Lambda_\pi]/(\beta\kappa)$. Since $\Lambda_r \leq 0$, $\Lambda_y > 0$, and $\Lambda_\pi > 0$, $\Omega_r < 0$. See the proof of Proposition 6.

eases credit conditions by raising the expected return on lending relative to the floor, weakening the credit-rationing friction.[57]

The history dependence of the commitment solution also implies gradualism in the withdrawal of accommodation. The lagged multiplier $\xi_{r,t-1}$ propagates past rationing episodes into the targeting rule, generating above-normal accommodation even after full lending is restored. Through the price-level targeting property of commitment, this accommodation is persistent: the rationing episode permanently shifts the implicit price-level target upward, generating a protracted period of above-normal inflation during the recovery. In the context of unconventional policy, this provides a rationale for gradual quantitative tightening: the promised future accommodation that made aggressive liquidity provision optimal during the crisis must be delivered during the recovery to maintain credibility and support the transition back to full lending.

6 Concluding remarks

This paper makes three broad contributions. First, it provides empirical evidence consistent with a link between interest-rate compression and bank lending incentives. Using euro area bank-level and aggregate data, the analysis documents that narrower spreads between market rates and the policy floor are associated with lower bank lending, consistent with the credit-rationing channel developed in the theoretical model.

Second, the paper develops a structural model that rationalises these findings. By embedding adverse selection into a New Keynesian framework with bank balance sheets and a policy corridor, the model delivers endogenous lending regimes and state-dependent transmission of liquidity policies. Liquidity injections operate through two opposing channels: a conventional demand channel and a credit-rationing channel that works through banks' lending incentives. Which channel dominates depends on risk, entry conditions, and the opportunity cost of lending, rather than on banks' access to funding. As a result, credit scarcity can arise for the real economy even as bank liquidity increases.

Third, the paper draws implications for monetary policy design. Endogenous lending distortions enter the welfare-relevant loss function as a credit wedge, generating a trade-off between stabilising inflation and closing the efficient output gap that is absent under full lending. Under

[57] This mirrors the analytical result in Section 4.5: both the demand channel and the credit-rationing channel raise inflation expectations, so QE remains expansionary at the ELB. Under commitment, the policymaker exploits this mechanism optimally.

discretion, optimal policy at the effective lower bound features a deflation bias: the policymaker restrains liquidity provision to preserve bank lending margins, with the bias increasing in the severity of adverse selection. Expected future lending regimes feed back into current policy through the expectations channel, with the risk of future rationing moderating the bias. Under commitment, the policymaker can ease credit conditions through forward guidance, by credibly promising future accommodation that raises lending profitability. This commitment generates history dependence in optimal policy: past rationing episodes oblige future accommodation, providing a rationale for gradualism in quantitative tightening. The promised accommodation that made aggressive liquidity provision optimal during the crisis must be delivered during the recovery, implying a protracted period of above-normal inflation to support the transition back to full lending.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work the author used Claude (Anthropic) and Refine.ink to obtain editorial feedback, check for errors, and improve the clarity and exposition of the manuscript. After using these tools, the author reviewed and edited the content as needed and takes full responsibility for the content of the published article.

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Online Appendices for "*Monetary Policy and the Credit Rationing Effects of Liquidity*"

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Appendix A Model equilibrium conditions

The competitive general equilibrium is determined by the following conditions:

$$1 = \mathbb{E}_t \left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}} \right] R_t \tag{A.1}$$

$$\frac{W_t}{P_t} = -\frac{U'(H_t)}{U'_t(C_t)} \tag{A.2}$$

$$\frac{W_t}{P_t} = (1-\alpha) MC_t z_t \left(\frac{K_{t-1}}{H_t} \right)^{\alpha} \tag{A.3}$$

$$R^s_t = \frac{\alpha MC_t z_t \left(\frac{K_{t-1}}{H_t} \right)^{\alpha-1} + (1-\delta) q^K_t}{q^K_{t-1}} \Pi_{t-1,t}, \tag{A.4}$$

$$R^r_t = \omega^r_t R^s_t \tag{A.5}$$

$$K_t = (1-\delta) K_{t-1} + I_t \left[1 - \frac{\phi_K}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right] \tag{A.6}$$

$$1 = q^K_t \left(\left[1 - \frac{\phi_K}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right] - \phi_K \left(\frac{I_t}{I_{t-1}} \right) \frac{I_t}{I_{t-1}} \right) + \mathbb{E}_t \left[\Lambda_{t,t+1} q^k_{t+1} \phi_K \left(\frac{I_{t+1}}{I_t} - 1 \right) \left(\frac{I_{t+1}}{I_t} \right)^2 \right]. \tag{A.7}$$

$$Y^W_t = z_t K^{\alpha}_{t-1} H^{1-\alpha}_t \tag{A.8}$$

$$Y_t = \frac{Y^W_t}{\Delta_t} \tag{A.9}$$

$$Y_t = C_t + I_t \tag{A.10}$$

$$1 = \xi \Pi^{\zeta-1}_{t-1,t} + (1-\xi) \left(\frac{\Omega_{1,t}}{\Omega_{2,t}} \right)^{1-\zeta} \tag{A.11}$$

$$\Delta_t = \xi \Pi^{\zeta}_{t-1,t} \Delta_{t-1} + (1-\xi) \left(\frac{\Omega_{1,t}}{\Omega_{2,t}} \right)^{-\zeta} \tag{A.12}$$

$$\Omega_{1,t} = Y_t \frac{1}{1-\frac{1}{\zeta}} MC_t + \xi\beta\mathbb{E}_t \left[\Lambda_{t,t+1}\Pi_{t,t+1}^{\zeta}\Omega_{1,t+1}\right] \tag{A.13}$$

$$\Omega_{2,t} = Y_t + \xi\beta\mathbb{E}_t \left[\Lambda_{t,t+1}\Pi_{t,t+1}^{\zeta-1}\Omega_{2,t+1}\right] \tag{A.14}$$

$$R_t = \frac{\Pi^*}{\beta}\left(\frac{Y_t}{\bar{Y}}\right)^{\gamma_y}\left(\frac{\Pi_{t-1,t}}{\Pi^*}\right)^{\gamma_\pi} \tag{A.15}$$

We then have the firm entry condition, and the capital market clearing linking the number of firms and capital:

$$F = \frac{\mathbb{E}_t\left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}}\left(\eta + (1-\eta)(1-\lambda)(1-p_{t+1})\,x_t^s\right)R_{t+1}^s\right] - \eta}{1-\mathbb{E}_t\left[\Lambda_{t,t+1}\left(\eta+(1-\eta)\left(\lambda x_t^s + (1-\lambda)\,x_t^r p_{t+1}\right)\right)\right]} q_t^K \tag{A.16}$$

$$K_t = \left(\eta + (1-\eta)\left(\lambda x_t^s + (1-\lambda)\,x_t^r\right)\right) f_t \tag{A.17}$$

The bank entry condition for liquidity ϕ:

$$1 = \mathbb{E}_t\left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}}\left(\underline{R}_t\left(1-\left[\lambda x_t^s + (1-\lambda)\,x_t^r\right]\frac{1}{\phi_t}\right)\right.\right.$$
$$\left.\left. + \left(\lambda x_t^s + (1-\lambda)\left(x_t^r - (1-p_{t+1})\,x_t^s\right)\right)\frac{1}{\phi_t}R_{t+1}^s\right)\right] \tag{A.18}$$

and conditions for lending (x_t^r and x_t^s):

$$\mathbb{E}_t\left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}}\left(R_{t+1}^s - \underline{R}_t\right)\right] = \varrho_t - \psi_t\frac{1}{1-\lambda} + \varphi_t^r\frac{1}{1-\lambda} \tag{A.19}$$

$$\mathbb{E}_t\left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}}\left(\left(\lambda + (1-\lambda)\,p_{t+1}\right)R_{t+1}^s - \underline{R}_t\right)\right] = \varrho_t + \varphi_t^r - \varphi_t^s \tag{A.20}$$

$$\varphi_t^s, \varphi_t^r, \varrho_t, \psi_t \geq 0 \tag{A.21}$$

$$\varphi_t^s x_t^s = 0 \tag{A.22}$$

$$\varphi_t^r\left(1-x_t^r\right) = 0 \tag{A.23}$$

$$\varrho_t\left(\bar{x}_t - \lambda x_t^s - (1-\lambda)\,x_t^r\right) = 0 \tag{A.24}$$

$$\psi_t\left(x_t^r - x_t^s\right) \tag{A.25}$$

$$\bar{x}_t = \min\{1, \phi_t\} \tag{A.26}$$

For the baseline numerical simulations, we use the King, Plosser and Rebelo (1988, KPR) class of utility with external habits in consumption:

$$U\left(C_t, H_t\right) = \frac{\left(\left[C_t - h\bar{C}_{t-1}\right]^{1-\chi}\left(1-H_t\right)^{\chi}\right)^{1-\sigma}}{1-\sigma} \tag{A.27}$$

For numerical simulations, we use a standard New Keynesian calibration shown in Table 3. Parameters for the novel part of the model (share of corporates, share of risky smalls, risky firm default) come from the calibration in Swarbrick (2023).

Parameter	Description	Value
β	Household discount factor	0.992
σ	Coefficient of relative risk aversion	1
χ	Consumption–leisure weight	$\bar{H} = 1/3$
α	Capital share in production	0.30
δ	Capital depreciation rate (quarterly)	0.023
ξ	Calvo price stickiness	0.75
ζ	Elasticity of substitution across goods	7
γ_π	Taylor rule inflation coefficient	1.5
γ_y	Taylor rule output gap coefficient	0.25
π^*	Inflation target (quarterly)	0.005
$\underline{R}$	Policy floor relative to policy rate (annualised)	-50 bps
η	Share of corporate firms	0.50
λ	Share of safe small firms	0.775
F	Firm entry cost	0.15
$1-\bar{p}$	Steady-state risky firm default rate (annual)	6%
ϕ_K	Investment adjustment cost parameter	0
h	Habits in consumption	0.5

Table 3: Baseline parameter values

Appendix B Simplified Model and Welfare

B.1 Setup and equilibrium conditions

The simplified version abstracts from capital accumulation and firm entry, fixing the number of firms at f. Firms require a single unit of outside finance, which converts into ω_t^i units of productive capacity. We set $\pi^* = \eta = 0$ and adopt separable preferences:

$$U\left(C_t, H_t\right) = \frac{C_t^{1-\sigma}}{1-\sigma} - \varphi_H \frac{H_t^{1+\varphi}}{1+\varphi} \tag{B.1}$$

Production is $y_t^i = Z_t[\omega_t^i]^\alpha[h_t^i]^{1-\alpha}$, with flexible labour markets implying $R_t^r = \omega_t^r R_t^s$. Denoting aggregate productivity $A_t \equiv Z_t[fx_{t-1}]^\alpha$ where $x_t \equiv \lambda x_t^s + 1 - \lambda$, steady-state labour subsidies s_W remove the monopolistic competition distortion, and a lending subsidy s_L ensures $x = 1$:

$$s_L = \max\left\{0\ ,\ \frac{\beta\lambda\left[1-(1-\lambda)(1-p)\right]+1-\lambda}{1-(1-\lambda)(1-p)} - 1\right\} \tag{B.2}$$

The non-linear equilibrium conditions are:

$$Y_t = \frac{1}{\Delta_t} A_t H_t^{1-\alpha} \tag{B.3}$$

$$1 = \beta \mathbb{E}_t\left[\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} \frac{R_t}{\Pi_{t,t+1}}\right] \tag{B.4}$$

$$\frac{W_t}{P_t} = \varphi_H C_t^\sigma H_t^\varphi \tag{B.5}$$

$$C_t = Y_t \tag{B.6}$$

$$\frac{W_t}{P_t} = (1+s_W)(1-\alpha)MC_t\frac{\Delta_t Y_t}{H_t} \tag{B.7}$$

$$A_t = \exp\left(z_t\right)\left[fx_{t-1}\right]^\alpha \tag{B.8}$$

$$R_t^s = \left[1 + \alpha(1+s_W)MC_t\frac{\Delta_t Y_t}{fx_{t-1}}\right]\Pi_{t-1,t} \tag{B.9}$$

$$\begin{aligned} 1 = \beta\mathbb{E}_t\Bigg[\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\Big(\underline{R}_t + \left(\lambda x_t^s(1+s_L)\left(R_{t+1}^s - \underline{R}_t\right)\right. \\ \left. + (1-\lambda)\left((1+s_L)R_{t+1}^s - \left(1-p_{t+1}^r\right)(1+s_L)R_{t+1}^s x_t^s - \underline{R}_t\right)\right)\frac{1}{\phi_t}\Big)\frac{1}{\Pi_{t,t+1}}\Bigg] \end{aligned} \tag{B.10}$$

$$\mathbb{E}_t\left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}}\left[\left(\lambda-(1-\lambda)\left(1-p_{t+1}^r\right)\right)(1+s_L)R_{t+1}^s - \lambda\underline{R}_t\right]\right] - \varrho_t\lambda - \psi_t = 0 \tag{B.11}$$

$$\min\left\{\varrho_t, \left(\phi_t - \lambda x_t^s - (1-\lambda)\right)\right\} = 0 \tag{B.12}$$

$$\min\left\{\psi_t, \left(1 - x_t^s\right)\right\} = 0 \tag{B.13}$$

together with the standard Calvo pricing conditions and the Taylor rule from Appendix A.

B.2 Key coefficients of the linearised credit wedge

Taking a log-linear approximation around the efficient steady state ($x = 1$, $\sigma = 1$) and expressing the credit wedge in terms of $(\tilde{y}_t, \pi_t, \hat{x}_t)$, the rationing condition can be written as:

$$\ln(x_t) = \Lambda_0 - \Lambda^D(r_t - \rho) + \Lambda^\nu \hat{\nu}_t + \Lambda_y \mathbb{E}_t[\tilde{y}_{t+1}] + \Lambda_\pi \mathbb{E}_t[\pi_{t+1}] + u_{r,t} \tag{B.14}$$

where the coefficients governing the two channels of monetary policy on lending are:

$$\Lambda^D \equiv \frac{1-\alpha}{1+\alpha\varphi}\frac{R^s}{R^s-1} \tag{B.15}$$

$$\Lambda^\nu \equiv \frac{1-\alpha}{1+\alpha\varphi}\frac{\lambda\underline{R}}{(1+s_L)(R^s-1)[\lambda-(1-p^r)(1-\lambda)]} \tag{B.16}$$

$$\Lambda_y \equiv \frac{(1-\alpha)+(1+\varphi)}{1+\alpha\varphi} \tag{B.17}$$

$$\Lambda_\pi \equiv \frac{1-\alpha}{1+\alpha\varphi}\frac{R^s}{R^s-1} = \Lambda^D \tag{B.18}$$

$\Lambda^D > 0$ governs the demand channel: lower r_t raises aggregate demand and the expected return on lending. $\Lambda^\nu > 0$ governs the credit-rationing channel: a wider spread to the floor increases the opportunity cost of holding reserves relative to lending. When the floor is constrained at the ELB, $\hat{\nu}_t = r_t - \rho$ and lending depends on r_t through $\Lambda_r \equiv \Lambda^D - \Lambda^\nu$. The exogenous shock term is:

$$u_{r,t} \equiv \frac{1-\alpha}{1+\alpha\varphi}\mathbb{E}_t[z_{t+1}] + \frac{R^s}{R^s-1}\frac{1-\alpha}{1+\alpha\varphi}\frac{p^r(1-\lambda)}{[\lambda-(1-p^r)(1-\lambda)]}\mathbb{E}_t[\hat{p}^r_{t+1}] \tag{B.19}$$

The liquidity constraint, when binding, yields an analogous condition with composite Υ-coefficients.

B.3 Welfare loss function

Taking a second-order expansion of utility around the efficient steady state with $\sigma = 1$, using $\hat{c}_t = \hat{y}_t$ and $\hat{y}_t - \hat{a}_t = \tilde{y}_t - \alpha\ln(x_{t-1})$:

$$\frac{U(C_t, H_t) - U(C, H)}{U_C Y} = -(\hat{\delta}_t - \hat{a}_t) - \frac{1}{2}\frac{1+\varphi}{1-\alpha}(\tilde{y}_t - \alpha\ln(x_{t-1}))^2 + \text{t.i.p.} \tag{B.20}$$

The quadratic term is the natural (flex-price) output gap $\tilde{y}_t - \alpha\ln(x_{t-1})$, which equals zero when prices are flexible: from the marginal cost expression $\widehat{mc}_t = \frac{1+\varphi}{1-\alpha}(\tilde{y}_t - \alpha\ln(x_{t-1}))$.

Using the standard Calvo result $\sum \beta^t \hat{\delta}_t = \frac{\zeta\xi}{2(1-\beta\xi)(1-\xi)} \sum \beta^t \pi_t^2$ and $\hat{a}_t = z_t + \alpha \ln(x_{t-1})$, defining the welfare loss $\mathcal{L} \equiv -\mathbb{E}_0 \sum \beta^t \widehat{U}_t$ and normalising:

$$\mathcal{L} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[-\lambda_x \frac{1-\alpha}{1+\varphi} \alpha \ln(x_{t-1}) + \frac{1}{2} \left(\pi_t^2 + \lambda_x (\tilde{y}_t - \alpha \ln(x_{t-1}))^2 \right) \right] \tag{B.21}$$

where $\lambda_x \equiv \frac{1+\varphi}{1-\alpha} \frac{(1-\beta\xi)(1-\xi)}{\zeta\xi} = \frac{\kappa}{\zeta}$. Without the credit friction ($\ln(x_{t-1}) = 0$), this collapses to the standard $\frac{1}{2}[\pi_t^2 + \lambda_x \tilde{y}_t^2]$.

Appendix C Derivations and proofs

C.1 Lending facility use

Proposition 7 *Banks never use the central bank standing lending facility if $\overline{R}_t > R_t^p$. However, banks will use the deposit (reserve) facility in equilibrium and so the opportunity cost of lending is $\underline{R}_t \forall t$.*

Proposition 7 establishes that without a source of liquidity risk, the banks will never resort to using the central bank lending facility if this charges a higher interest rate than the main liquidity operation. So it truly is a last resort facility.

Proof: Without a source of liquidity risk, banks know their liquidity requirements with certainty at the time of portfolio allocation. Since funds are available through the main refinancing operation at rate $R_t^p < \overline{R}_t$, a bank facing a liquidity shortfall can always obtain funds at R_t^p rather than borrowing at the marginal lending facility rate $\overline{R}_t$. The lending facility is therefore strictly dominated and is never used in equilibrium. □

C.2 Proof of proposition 1

The bank's first-order conditions for x_t^r and x_t^s are:

$$\mathbb{E}_t \left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}} \left(R_{t+1}^s - \underline{R}_t \right) \right] = \varrho_t - \frac{\psi_t}{1-\lambda} + \frac{\varphi_t^r}{1-\lambda} \tag{C.1}$$

$$\mathbb{E}_t \left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}} \left((\lambda + (1-\lambda) p_{t+1}) R_{t+1}^s - \underline{R}_t \right) \right] = \varrho_t + \varphi_t^r - \varphi_t^s \tag{C.2}$$

Subtracting (C.1) from (C.2):

$$-(1-\lambda)\mathbb{E}_t\left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}}(1-p_{t+1})R^s_{t+1}\right] = -\varphi^s_t + \frac{\psi_t}{1-\lambda} - \frac{\lambda}{1-\lambda}\varphi^r_t \tag{C.3}$$

The left-hand side is strictly negative since $(1-p_{t+1}) > 0$, $R^s_{t+1} > 0$, and $\Lambda_{t,t+1}/\Pi_{t,t+1} > 0$. If $x^s_t > 0$ then $\varphi^s_t = 0$ by complementary slackness, giving:

$$\frac{\psi_t}{1-\lambda} - \frac{\lambda}{1-\lambda}\varphi^r_t < 0 \quad \Rightarrow \quad \psi_t < \lambda\varphi^r_t \tag{C.4}$$

Since $\psi_t \geq 0$, this requires $\varphi^r_t > 0$, which by complementary slackness implies $x^r_t = 1$.

C.3 Proof of proposition 2

By Proposition 1, $x^r_t = 1$ whenever $x^s_t > 0$, so $\varphi^r_t > 0$ in all three regimes. Under the maintained assumption $\varphi^s_t = 0$, combining the bank's first-order conditions for x^r_t and x^s_t yields:

$$\mathbb{E}_t\left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}}\left(\lambda(R^s_{t+1} - \underline{R}_t) - (1-\lambda)(1-p_{t+1})R^s_{t+1}\right)\right] = \lambda\varrho_t + \psi_t \tag{C.5}$$

Since $\varrho_t, \psi_t \geq 0$, the LHS is non-negative.

No credit rationing. When (4.1) holds strictly, the LHS of (C.5) is positive, requiring $\lambda\varrho_t + \psi_t > 0$: either the liquidity constraint binds ($\varrho_t > 0$) or there is pooling ($\psi_t > 0$). In either case, rationing does not occur.

Regime 3 (Credit rationing). When (4.1) holds with equality, $\lambda\varrho_t + \psi_t = 0$, so $\varrho_t = \psi_t = 0$: there is no pooling and the liquidity constraint is slack (banks hold excess reserves). Banks optimally set $x^s_t < 1$ because the marginal revenue from a safe loan, $\lambda(R^s_{t+1} - \underline{R}_t)$, exactly equals the marginal information rent cost, $(1-\lambda)(1-p_{t+1})R^s_{t+1}$.

Regimes 1 and 2. When no rationing occurs, the regime depends on whether equilibrium bank liquidity is sufficient to fund all firms. The bank free-entry condition determines ϕ_t. When $x^s_t = 1$ and $\phi_t \geq 1$, evaluating the free-entry condition yields condition (4.2).

Regime 1 (Abundant liquidity). When both (4.1) and (4.2) hold, $\phi_t \geq x_t = 1$ and $\psi_t > 0$ enforces pooling. All firms are funded with excess reserves ($\varrho_t = 0$).

Regime 2 (Scarce liquidity). When (4.1) holds but (4.2) fails, the expected return on the bank's portfolio is insufficient to attract enough entry for $\phi_t \geq 1$. The liquidity constraint binds ($\varrho_t > 0$, $\phi_t = x_t < 1$), restricting $x_t^s < 1$ despite positive lending incentives ($\psi_t = 0$). □

C.4 Proof of proposition 3

From Proposition 2, credit rationing occurs when:

$$\mathbb{E}_t \left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}} \left(\lambda(R^s_{t+1} - \underline{R}_t) - (1-\lambda)(1-p_{t+1})R^s_{t+1} \right) \right] = 0 \tag{C.6}$$

The interest on reserves $\underline{R}_t$ enters this condition with coefficient $-\lambda < 0$. For any given R^s_{t+1} and p_{t+1}, reducing $\underline{R}_t$ (equivalently, raising $\nu_t = r_t - \underline{r}_t$) strictly increases the LHS. Away from the effective lower bound, the policymaker can always lower $\underline{R}_t$ sufficiently to make the LHS strictly positive, ensuring condition (4.1) holds and credit rationing does not occur.

The liquidity constraint threshold (4.2):

$$\mathbb{E}_t \left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}} [1 - (1-\lambda)(1-p_{t+1})] R^s_{t+1} \right] \geq 1 \tag{C.7}$$

does not depend on $\underline{R}_t$. The spread instrument therefore cannot prevent this constraint from binding.

The linearised model confirms this structure: the rationing condition (5.7) contains $\Lambda^\nu \hat{\nu}_t$ with $\Lambda^\nu > 0$, so widening the spread relaxes the constraint, while the liquidity condition (5.8) is independent of $\hat{\nu}_t$. □

C.5 Proof of proposition 4

When $\ln(x_t) = 0$, the feasibility constraint binds ($\xi_{x,t} \geq 0$) while the rationing and liquidity constraints are slack ($\xi_{r,t} = \xi_{l,t} = 0$). From the FOC for r_t: $\mu_{y,t} = -\Lambda_r \xi_{r,t} - \Upsilon_r \xi_{l,t} = 0$. From the FOC for π_t: $\mu_{\pi,t} = -\pi_t$. Substituting both into the FOC for $\tilde{y}_t$:

$$\lambda_x(\tilde{y}_t - \alpha \ln(x_{t-1})) + \kappa \pi_t = 0 \tag{C.8}$$

which gives (5.13). When $\ln(x_{t-1}) = 0$, this reduces to $\pi_t = -(\lambda_x/\kappa)\tilde{y}_t$. □

C.6 Proof of proposition 5

When the ELB binds, $\nu_t = r_t - \underline{r}^{ELB}$ and the rationing constraint depends on r_t through $-\Lambda_r(r_t - \rho)$. Under active rationing ($\xi_{r,t} > 0$) with the liquidity constraint slack ($\xi_{l,t} = 0$) and $\ln(x_t) < 0$ ($\xi_{x,t} = 0$), the discretionary FOCs give: $\mu_{\pi,t} = -\pi_t$; $\lambda_x(\tilde{y}_t - \alpha\ln(x_{t-1})) + \kappa\pi_t + \mu_{y,t} = 0$; and $\mu_{y,t} = -\Lambda_r\xi_{r,t}$. Combining yields (5.14).

For the recursion, since $\ln(x_t)$ affects welfare only from $t+1$ onwards, the FOC for $\ln(x_t)$ is:

$$\xi_{r,t} = \beta\lambda_x\frac{1-\alpha}{1+\varphi}\alpha + \beta\lambda_x\alpha\mathbb{E}_t[\tilde{y}_{t+1} - \alpha\ln(x_t)] + \beta\kappa\alpha\mathbb{E}_t[\pi_{t+1}]$$

The targeting rule holds in all future states, giving $\lambda_x(\tilde{y}_{t+1} - \alpha\ln(x_t)) + \kappa\pi_{t+1} = \Lambda_r\xi_{r,t+1} + \Upsilon_r\xi_{l,t+1}$. Substituting yields (5.15). □

C.7 Proof of proposition 6

Under commitment, π_t and $\tilde{y}_t$ appear in period-$(t-1)$ constraints through expectations, generating lagged multiplier terms absent under discretion. The FOCs are:

$$\pi_t + \mu_{\pi,t} - \mu_{\pi,t-1} - \tfrac{1}{\beta}\mu_{y,t-1} - \tfrac{\Lambda_\pi}{\beta}\xi_{r,t-1} - \tfrac{\Upsilon_\pi}{\beta}\xi_{l,t-1} = 0 \tag{C.9}$$

$$\lambda_x(\tilde{y}_t - \alpha\ln(x_{t-1})) - \kappa\mu_{\pi,t} + \mu_{y,t} - \tfrac{1}{\beta}\mu_{y,t-1} - \tfrac{\Lambda_y}{\beta}\xi_{r,t-1} - \tfrac{\Upsilon_y}{\beta}\xi_{l,t-1} = 0 \tag{C.10}$$

$$\mu_{y,t} + \Lambda_r\xi_{r,t} + \Upsilon_r\xi_{l,t} = 0 \tag{C.11}$$

Multiplying (C.9) by κ, adding (C.10), and using (C.11) to eliminate $\mu_{y,t}$ and $\mu_{y,t-1}$ yields (5.16), where $\Omega_r \equiv [(1+\kappa)\Lambda_r - \Lambda_y - \kappa\Lambda_\pi]/(\beta\kappa)$ and Ω_l is defined analogously.

For the recursion, the FOC for $\ln(x_t)$ is:

$$\xi_{r,t} + \xi_{l,t} + \xi_{x,t} = \beta\lambda_x\tfrac{1-\alpha}{1+\varphi}\alpha + \beta\lambda_x\alpha\mathbb{E}_t[\tilde{y}_{t+1} - \alpha\ln(x_t)] - \beta\kappa\alpha\mathbb{E}_t[\mu_{\pi,t+1}] \tag{C.12}$$

Using the forward targeting rule and the forward (C.9) to express $\lambda_x(\tilde{y}_{t+1} - \alpha\ln(x_t)) - \kappa\mu_{\pi,t+1}$ in terms of multipliers, the $\mu_{\pi,t}$ and π_{t+1} terms cancel, leaving (under rationing, $\xi_{l,t} = \xi_{x,t} = 0$):

$$\Gamma_r\xi_{r,t} = \beta\lambda_x\tfrac{1-\alpha}{1+\varphi}\alpha + \beta\alpha\mathbb{E}_t[\Lambda_r\xi_{r,t+1} + \Upsilon_r\xi_{l,t+1}]$$

where $\Gamma_r = 1 - \alpha(\Lambda_y - \Lambda_r)$, giving (5.17). For the special case, setting $\xi_{r,t} = \xi_{l,t} = \xi_{r,t-1} =$

$\xi_{l,t-1} = 0$ and $\ln(x_{t-1}) = 0$ in (5.16) gives $\pi_t + (\lambda_x/\kappa)\tilde{y}_t = \mu_{\pi,t-1}$. From (C.10) with zero credit multipliers: $\mu_{\pi,t} = (\lambda_x/\kappa)\tilde{y}_t$, so $\mu_{\pi,t-1} = (\lambda_x/\kappa)\tilde{y}_{t-1}$, yielding $\pi_t = -(\lambda_x/\kappa)(\tilde{y}_t - \tilde{y}_{t-1})$. □

Appendix D Empirical Results

This appendix reports supplementary bank-level results supporting the aggregate analysis in Section 2.

D.1 Robustness of the aggregate balance-sheet relationships

Table 4 reports the spread coefficient under three estimators. Because the spread is an aggregate, persistent series, two-way clustering may understate its standard error; the asset-weighted quarterly aggregate with a Newey-West correction addresses this, giving a loan coefficient of +0.041 ($t = 4.3$).

Significance rests on the weighting. The loan coefficient is significant at one percent under asset weighting and only marginally so under equal weighting (+0.034, $p = 0.09$), with the same sign and magnitude either way. This is expected: the effect concentrates in the largest banks, which hold almost all of the assets in the sample (Table 2), so asset weighting recovers the aggregate-representative effect.

The interbank-rate coefficient is negative and significant throughout. The implied effect of the interbank rate holding the floor fixed, the sum of the two coefficients, is +0.029 ($p = 0.03$) under asset weighting and a smaller, less precise +0.014 under equal weighting.

	$\ln L_t$	$\ln Res_t$
Asset-weighted, two-way cluster	0.048^{***} (0.013)	-0.172^{***} (0.062)
Equal-weighted, two-way cluster	0.034^{*} (0.020)	-0.104^{*} (0.057)
Asset-weighted aggregate, Newey-West	0.041^{***} (0.010)	-0.201 (0.131)

Notes: Each cell is the coefficient on the spread to the floor, s_t, per 25 basis points, from a separate regression with the controls of Table 1. The first two rows are the bank-level panel with bank fixed effects (4,161 loan and 5,762 reserve observations), differing only in whether observations are weighted by bank assets; standard errors are clustered by bank and quarter. The third row collapses the panel to 48 asset-weighted quarterly aggregates and applies a Newey-West correction at lag four. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 4: The floor-spread coefficient under alternative weighting and serial-correlation corrections

D.2 Cross-sectional heterogeneity across size cuts and fixed-effects schemes

Table 5 reports the reserve-richness interaction across size cuts, under both fixed-effects schemes of Table 2; the top-quartile row reproduces that table. The interaction is positive throughout the size distribution. Under bank and quarter fixed effects it is significant from the top 30% of banks through the top 20%, and insignificant only when the cut is broadened to the top half. Under core/periphery-by-quarter fixed effects it is significant at every cut and larger as the cut narrows. The deposit-funding and capitalisation interactions are insignificant at every cut and are omitted.

	Bank + quarter FE (1)	Core/periph. × quarter FE (2)	Banks	Obs.
Top 50%	0.006 (0.005)	0.010^{**} (0.005)	77	2,076
Top 30%	0.015^{**} (0.007)	0.019^{**} (0.008)	70	1,932
Top 25% (quartile)	0.018^{**} (0.007)	0.022^{***} (0.008)	62	1,784
Top 20%	0.014^{**} (0.007)	0.024^{**} (0.011)	53	1,562

Notes: Each cell is the coefficient on $s_t\times$ reserve-richness from the three-interaction specification of equation (2.2), estimated on banks above the stated percentile of mean assets. Standard errors clustered by bank in parentheses. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table 5: The reserve-richness interaction across size cuts

Appendix E Collateral extension

This appendix extends the bank's problem to allow firms to pledge personal wealth as collateral. We show that collateral shifts the threshold at which credit rationing occurs but does not eliminate the mechanism.

E.1 Setup

Each firm is endowed with personal wealth $\bar{c} \geq 0$ per unit of capital, independent of type. This wealth is unrelated to the project being financed and represents pledgeable assets such as the entrepreneur's personal real estate or savings. The bank's contract for type $i \in \{s, r\}$ is now (τ_t^i, x_t^i, c_t^i): a repayment rate, an approval probability, and a collateral requirement $c_t^i \in [0, \bar{c}]$. If the firm repays, the collateral is returned. If the firm defaults, the bank seizes c_t^i and recovers its full value.[1]

E.2 Modified constraints

Since safe firms never default, their collateral is always returned. Collateral is therefore costless for the safe type, and the participation constraint is unchanged from (3.2). This asymmetry is the key to the Bester mechanism: a risky firm mimicking the safe contract now faces expected collateral loss $(1 - p_{t+1})c_t^s$ per approved loan upon default. Higher c_t^s makes mimicking more costly, so the bank sets $c_t^s = \bar{c}$. With the participation constraint binding ($\tau_t^s = R_{t+1}^s$), the incentive compatibility constraint (3.3) becomes:

$$\left[p_{t+1}(R_{t+1}^r - \tau_t^r) - (1 - p_{t+1})c_t^r\right] x_t^r \;\geq\; \left[(1 - p_{t+1})(R_{t+1}^s - \bar{c})\right] x_t^s, \tag{E.1}$$

where the right-hand side uses $p_{t+1}R_{t+1}^r = R_{t+1}^s$. The modified information rent per safe loan is $(1 - p_{t+1})(R_{t+1}^s - \bar{c})$, reduced by $(1 - p_{t+1})\bar{c}$ relative to the baseline.

E.3 Bank optimisation

The bank chooses $(x_t^s, x_t^r, \tau_t^r, c_t^r)$ to maximise expected lending profit:

$$\mathbb{E}_t\left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}}\left(\lambda\, x_t^s(R_{t+1}^s - \underline{R}_t) + (1-\lambda)\, x_t^r[p_{t+1}\tau_t^r + (1 - p_{t+1})c_t^r - \underline{R}_t]\right)\right], \tag{E.2}$$

subject to the IC (E.1), feasibility $x_t^s \in [0, 1]$, $x_t^r \in [0, 1]$, and $c_t^r \in [0, \bar{c}]$.

The first-order conditions yield three results that parallel the baseline.

First, c_t^r is indeterminate: along the binding IC, any increase in c_t^r is exactly offset by a decrease in τ_t^r, leaving bank revenue and the equilibrium allocation unchanged. We set $c_t^r = 0$ without loss of generality.

Second, $x_t^r = 1$. Each additional risky loan earns expected net revenue $\mathbb{E}_t[\Lambda_{t,t+1}\Pi_{t,t+1}^{-1}(R_{t+1}^s - \underline{R}_t)] > 0$ and relaxes the IC by increasing the risky type's surplus from truthful revelation. The introduction of collateral does not alter this result.

Third, the first-order condition for x_t^s equates the marginal revenue from an additional safe loan with the marginal information-rent cost. Setting $c_t^r = 0$ and $x_t^r = 1$, interior rationing ($x_t^s < 1$)

[1] Assuming no deadweight loss from seizure is conservative: it maximises the screening power of collateral and therefore provides the strongest test of whether collateral eliminates credit rationing.

occurs when:

$$\mathbb{E}_t\left[\frac{\Lambda_{t,t+1}}{\Pi_{t,t+1}}\left(\lambda\big(R^s_{t+1}-\underline{R}_t\big)-(1-\lambda)(1-p_{t+1})(R^s_{t+1}-\bar{c})\right)\right]=0. \tag{E.3}$$

This generalises (4.4): the information-rent cost $(1-\lambda)(1-p_{t+1})R^s_{t+1}$ is replaced by $(1-\lambda)(1-p_{t+1})(R^s_{t+1}-\bar{c})$. The baseline is recovered by setting $\bar{c}=0$.

E.4 Implications

Three results follow from (E.3).

1. *Threshold shift.* Credit rationing occurs when $\lambda(R^s_{t+1}-\underline{R}_t)<(1-\lambda)(1-p_{t+1})(R^s_{t+1}-\bar{c})$. Since the right-hand side is strictly decreasing in $\bar{c}$, higher collateral shrinks the rationing region. However, for any $\bar{c}<R^s_{t+1}$, the right-hand side remains strictly positive and rationing can occur for sufficiently high default risk or a sufficiently tight policy corridor. The entire structure of the model, including the dependence of rationing on $\underline{R}_t$ and the competing channels of liquidity policy, is preserved.

2. *Full separation.* The information rent is non-positive (and hence rationing is eliminated for all parameter values) if and only if $\bar{c}\geq R^s_{t+1}$. This requires the entrepreneur's pledgeable personal wealth per unit of capital to exceed the gross return on capital. Since the model's borrower population consists of firms requiring external finance precisely because they lack sufficient internal funds, this condition is not satisfied for the relevant margin.

3. *Procyclicality.* If $\bar{c}$ depends on asset prices (personal real estate, existing business equipment), it is procyclical. In downturns, p_{t+1} falls and $\bar{c}$ falls simultaneously, both pushing the information rent $(1-p_{t+1})(R^s_{t+1}-\bar{c})$ higher and the rationing condition towards binding. The collateral screening mechanism is therefore weakest in the states of the world where the credit-rationing channel is most relevant.

The above analysis considers the most favourable case for collateral as a screening device. The empirical picture is less clear-cut: much of the literature finds that *riskier* borrowers post more collateral, consistent with banks using collateral to mitigate losses on observably risky loans rather than to screen unobserved types (Berger and Udell, 1990; Jiménez et al., 2006). Even studies that find evidence for the screening channel find it operating alongside observed-risk explanations, not instead of them (Berger et al., 2016). This suggests that collateral in practice attenuates adverse selection but does not resolve it, reinforcing the case for the rationing mechanism studied in this paper.

The remaining equilibrium conditions (the liquidity constraint threshold, the Phillips curve, the IS curve, and the welfare approximation) are unaffected, since collateral enters only through the modified information rent in the rationing condition. The corollaries to Proposition 3 continue to hold, with the sole addition that the rationing incentive now also falls in $\bar{c}$.

Appendix F Additional simulations and figures

This appendix contains the results from further simulations. Figure 7 repeats the high vs low risk economy simulations to a QE programme with investment adjustment costs.

We next consider preferences of the type proposed by Jaimovich and Rebelo (2009, JR), which allow for a weak short-run wealth effect on labour supply. These take the form:

$$U(C_t, H_t) = \frac{1}{1-\sigma}\left(C_t - \chi H_t^{\theta} X_t\right)^{1-\sigma} \tag{F.1}$$

where $X_t = C_t^{\gamma} X_{t-1}^{1-\gamma}$. When calibrated with ($\gamma = 0.2$) and an inverse Frisch elasticity $\theta = 2.5$, these preferences substantially dampen the consumption response to lower interest rates. Figures 8 and 9 shows the small/medium/large simulations with JR preferences without and

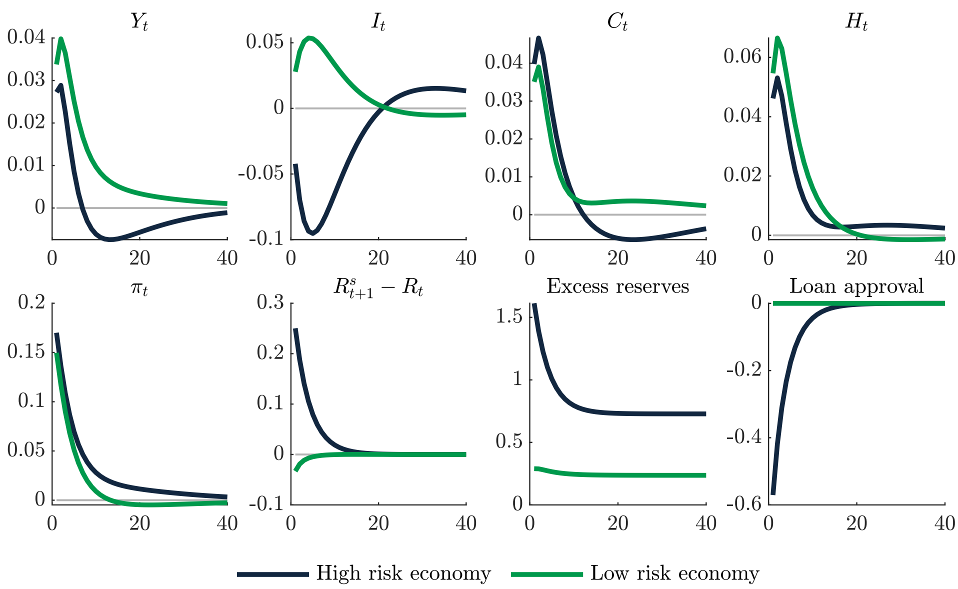

Figure 7: Impulse response functions to an unexpected temporary 'QE' programme in model with investment adjustment costs ($\phi_K = 4$). Plots in the top row show % deviation from steady state. The bottom row shows ppt deviation except for excess reserves which plots the ratio of reserves to stock of loans. Per annum risky firm default rate is 12% (high risk) and 2% (low risk).

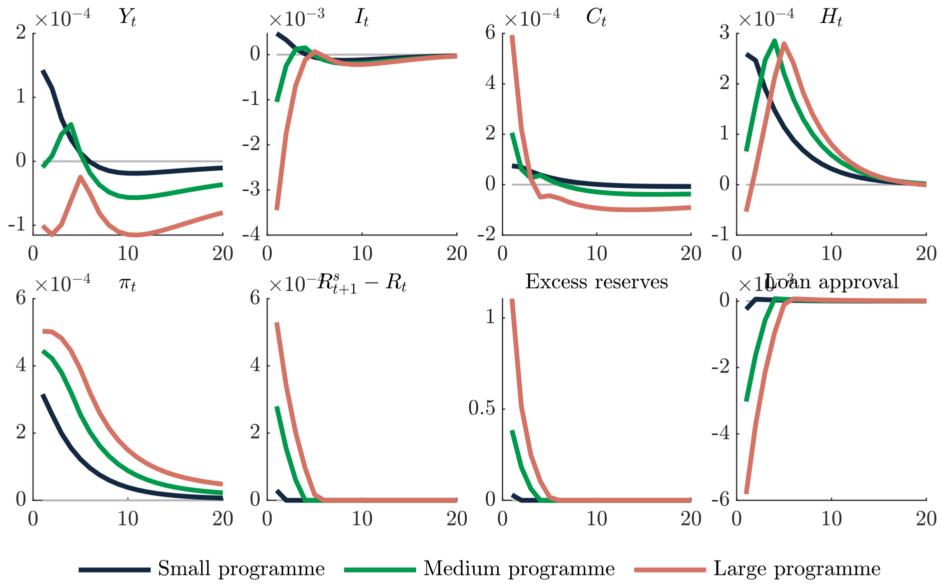

Figure 8: Impulse response functions to a temporary 'QE' programme with Jaimovich-Rebelo preferences, calibrated with a weak wealth effect on labour. Plots in the top row show % deviation from steady state. The bottom row shows ppt deviation except for excess reserves which plots the ratio of reserves to stock of loans.

with investment adjustment costs, respectively.

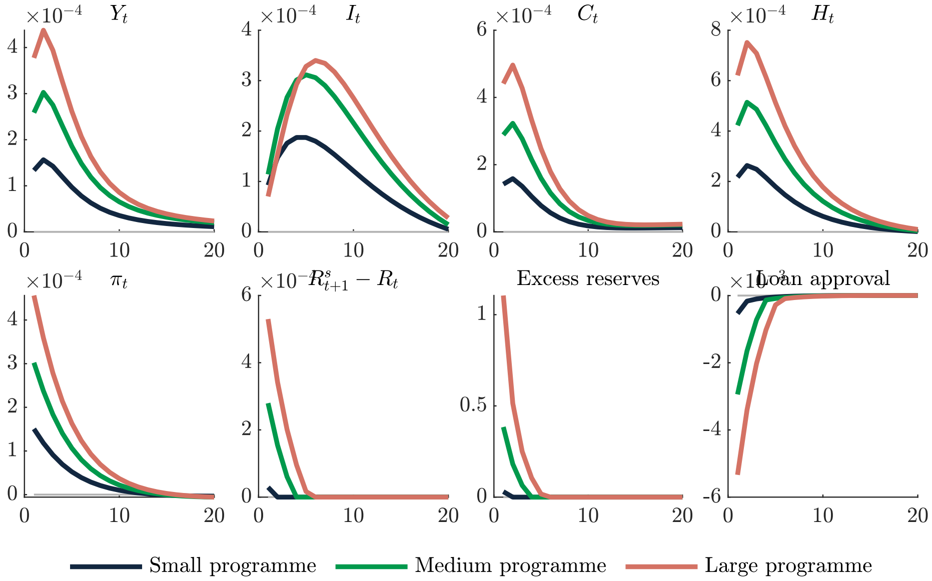

Figure 9: Impulse response functions to a temporary 'QE' programme with Jaimovich-Rebelo preferences, calibrated with a weak wealth effect on labour, and investment adjustment costs ($\phi_K = 4$). Plots in the top row show % deviation from steady state. The bottom row shows ppt deviation except for excess reserves which plots the ratio of reserves to stock of loans.

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