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Carlo Altavilla, Massimo Rostagno,
Julian Schumacher

When banks hold back: credit and liquidity provision

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Abstract

Banks are reluctant to tap central bank backup liquidity facilities and use the borrowed funds for loans to the real economy. We show that excessively parsimonious borrowing and lending can arise in a stigma-free model where the banking sector has an incentive to overissue deposits. Banks don't heed the central bank's call for more credit to finance investment because they simply ignore the collective gains from stronger activity in their atomistic decisions. Central banks can address this market failure by disintermediating market-based finance. A lender-of-last-resort (LOLR) system in which the central bank offers liquidity liberally but on non-concessionary conditions improves over a pure laissez-faire arrangement, where asset liquidation in the marketplace is the only source of emergency liquidity. But under LOLR banks remain reluctant to intermediate. Credit easing (CE) and quantitative easing (QE), instead, can stimulate bank borrowing and repair the broken nexus between liquidity provision and credit. Empirical analysis using bank-level and loan-by-loan data supports our model predictions. We find no empirical connection between loans and borrowed reserves obtained from conventional refinancing facilities. In contrast, there is a robust connection between loans and structural sources of liquidity: reserves borrowed under a CE program or non-borrowed, i.e. acquired from a QE injection. We also find that firms with greater exposure to banks borrowing in a CE program or holding larger volumes of non-borrowed reserves increase employment, sales, and investment.

JEL Codes: E5; E43; G2

Keywords: Lending of last resort, credit easing, quantitative easing, loans, reserves

Non-technical summary

Over the past four decades, an influential body of economic research has highlighted banks' inherent tendency to overextend credit, often fuelling financial booms that end in crises. This research has inspired a far-reaching regulatory reform agenda that has strengthened the global financial system, particularly banks. In parallel, however, analysts have long observed commercial banks borrowing from central banks only reluctantly, using the borrowed liquidity sparingly for credit creation.

This paper investigates a factor behind banks' reluctance to intermediate that has been overlooked in prior research. In a model of banking where borrowing from the central bank is stigma-free, we demonstrate that overly cautious borrowing and lending can emerge even when banks have an underlying incentive to overissue deposits and overextend credit. We show that a lending of last resort facility can enhance welfare relative to a laissez-faire regime in which the only source of emergency liquidity for banks in the face of a deposit run is fire-sale asset liquidation. However, banks' failure to internalise the superior social objective leads to deficient bank intermediation and under-investment in a lender-of-last-resort regime of liquidity provision. Credit easing and quantitative easing policies – changing the nature of liquidity provision into something cheaper and more persistent – can nudge banks towards levels of intermediation activity that match social optima.

Using bank-level and loan-level data, the empirical analysis supports the predictions of our model. We find no significant relationship between loans and reserves borrowed in standard refinancing facilities. In contrast, there is a strong connection between loans and structural sources of liquidity, such as reserves obtained through credit easing programs or those injected through quantitative easing interventions. Furthermore, we show that firms with higher exposure to banks participating in CE programs or holding larger volumes of non-borrowed reserves exhibit significant increases in employment, sales, and investment.

1 Introduction

Over the past forty years, an influential strand of economic literature has pointed to banks' inherent tendency to overextend their exposures and occasionally fuel financial booms that end badly. Among many other contributions, the literature on bank credit cycles and fragile banking includes Bernanke and Gertler (1989), Kiyotaki and Moore (1997), Diamond and Rajan (2001), Rajan (2006), Adrian and Shin (2008), Lorenzoni (2008), Shleifer and Vishny (2009), Stein (2012) and Acharya and Rajan (2022). This body of research deserves much recognition, because it arguably contributed to the rollout of an ambitious regulatory reform that put the world financial system – and especially banks – on safer ground (see e.g. BCBS 2015, BCBS 2016). At the same time, on a somewhat contrarian note, analysts have long observed commercial banks borrowing from central banks only reluctantly and using the borrowed liquidity sparingly for credit creation.

Already in the 1920s, Federal Reserve (Fed) economists Winfield Riefler and Randolph Burgess noticed that banks' reluctance to borrow from the discount window gave the Fed's open market operations an extra leverage over credit conditions, especially in a tightening phase. An open-market sale of securities would pressure banks into tapping the discount window to offset the loss of cash. However, they would do so unwillingly. In short order, they would put in place remedial strategies to call in outstanding loans and curtail further lending, in a bid to replenish their stock of reserves organically and extinguish Fed credit (Brunner and Meltzer, 1964, and Meltzer, 1976 and 2003). The same behaviour has been detected ever since across a variety of cyclical and market conditions as well as regulatory environments.[1] Friedman and Schwartz (1963), for example, pointed out that, even in the throes of the Great Depression, most banks remained hesitant to borrow from the discount window. After 1982, the unwillingness of banks to borrow when borrowed reserves were used as an operating target by the Federal Open Market Committee (FOMC) weakened interest rate control to the point that the Fed saw a return to an interest-rate-targeting framework as desirable (Meulendyke, 1998, Peristiani, 1998). More recently, a second test for banks' propensity to

[1] More or less permissive regulatory environments have implications for the maximum intermediation capacity of commercial banks.

seek central bank loans in strained circumstances came with the Great Financial Crisis (GFC). Even in those conditions, many banks faced with a drain of cash would often eschew refinancing with the central bank and rather refuse to make markets, dump assets at deep discounts and cut back credit to restock their liquidity reservoirs (Bernanke, 2009; Armantier *et al 2015*).[2] In 2021, the Fed launched a new permanent backstop instrument, the Standing Repo Facility (SRF), specifically designed as an open-door liquidity gateway to serve the system at all times. The professed intention was to convince banks that, unlike under the discount window, access to SRF would be unremarkable and uninformative. Although, admittedly, current ample reserve conditions make the new instrument unattractive to many potential borrowers, the fact is that SRF funds have met with scarce demand to date. In a few instances the SRF has manifestly failed to blunt upside volatility in market rates.[3]

A question is what explains such a behaviour. Stigma is mentioned as the most persuasive proximate cause (Duke, 2010; Anbil, 2018; Armantier and Holt, 2020). A high share of central bank credit in the bank's funding structure can lead depositors, creditors, and analysts to conclude that, if the institution were in a good financial position, it would borrow privately at the market rate.[4] If it prefers central bank credit instead – so the reasoning goes – that must be evidence of financial strains. Internalising this thinking, the bank feels stigmatised when visiting the lending facility, and ultimately becomes disinclined to borrow from the central

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[2] Armantier *et al*. (2015) analyses TAF borrowing from December 2007 to September 2008 and finds that banks were willing to pay a hefty premium to avoid borrowing from the discount window. In other words, some banks were willing to pay higher interest rates in the market or at the TAF than the ones they could have obtained at the discount window.

[3] See e.g. Reuters, "Key US short-term rate surges amid month-end turbulence", 1 October 2024. SRF provides primary dealers and banks with access to overnight liquidity. The new facility accepts only high-quality collateral (Treasuries and agency securities) and its rate is determined by auction.

[4] Although neither the Fed or the European Central Bank (ECB) disclose the identity of borrowing banks, use of the discount window or participation in the weekly lending operations can sometimes be inferred indirectly by financial market participants and rumours are a factor as well (Holland, 1990, and Forsyth, 1990, for the US, or Wilson, 2012, or Enrich, 2012, for the euro area). The literature on stigma effects is very large, including the papers mentioned in the main text. A question around the stigma-based explanation is the following, however: if the liquidity deficit is systemic rather than idiosyncratic, why should the stakeholders draw negative conclusions about the viability of the bank's business model?

bank.[5] While convincing, this diagnosis doesn't seem exhaustive, however. As mentioned above, banks' reluctance to borrow has a historical record that straddles across different monetary regimes and is robust to changes in the governance of liquidity provision.

Regardless of the underlying motives, all this is troubling for policymakers. First, if banks refuse to take up central bank credit even amidst acute liquidity shortages, then the lender-of-last-resort (LOLR) function of monetary policy is severely diminished. Yet, LOLR is a key control tool to quell turmoil in funding markets before dislocations escalate to macro-systemic proportions. Secondly, in bank-centred economies, and even outside crises, the central bank typically enlists banks in ensuring that credit keeps flowing to the economy at rates consistent with balanced growth. Bank borrowing shortfalls in regular refinancing operations may then easily translate into a permanent lending deficit. In Rostagno *et al*. (2021a), two of us describe a 2013-2014 episode in which banks' widescale reimbursement of central bank liquidity in the euro area came into conflict with the central bank's objective to kickstart credit and reflate the economy.

In this paper we focus on banks' reluctance to intermediate, which we define as their scant propensity to access regular central bank facilities and convert borrowings into loans to the broad economy. We offer a simple micro-foundation for such a reluctance. Interestingly, we show that excessively parsimonious borrowing and lending can arise in a stigma-free model that otherwise allows for a banking sector with a strong incentive to over-extend itself. Banks don't respond to the authority's call for more lending to finance investment because, in the model, they simply ignore collective gains in their atomistic decisions. We show how a central bank can address this market failure by disintermediating market finance. Balance sheet policies such as credit easing and quantitative easing can repair the broken nexus between

[5] There is evidence that central banks and supervisors have occasionally taken a dim view of banks' recourse to short-term lending facilities, which can add to a sense of wrongdoing when banks are forced to borrow. For example, until the early 2000s the Fed had a tradition of discouraging discount window borrowing through various restrictions on access to the window. Occasionally, it issued regulations delineating "appropriate" and "inappropriate" purposes for borrowing from the window and added a requirement in 1973 that banks must first exhaust alternative sources of credit. Throughout the 1980s, in particular, the Fed encouraged depository institutions to improve liquidity planning and to find more stable sources of funds. Although the Fed reversed this approach in 2003, creating the Primary Credit program, the legacy of this prior attitude is seen as having endured. See Peristiani (1998).

liquidity provision and credit. There are two parts to this paper, one theoretical and one empirical.

In the theory sections, we work with a variant of the model described in Stein (2012). As in Stein (2012), in our setting banks find it attractive to finance investment by issuing sight deposits: households value liquidity for its convenience and are ready to accept a lower interest rate on deposit balances. So, deposit funding is cheap and banks seek to expand their balance sheets to the maximum that their stakeholders allow to back a larger pool of low-cost deposits. The technology employed in the sector that borrows from banks is stochastic, and the entire investment made in that sector can be destroyed in a tail event. Knowing this, households may decide to withdraw their deposits and run away in a bad state of the economy. If that happens, bank assets need to be liquidated in a distressed-asset market for banks to be able to make good on their deposit liabilities. The policy authority has two priorities: ensure financial stability and maximise consumption. Under the financial-stability leg of its mandate, as in Stein (2012), the policy authority is concerned that banks may over-extend themselves, accepting too lightly the tail risk of fire sales in exchange for higher margins in a good state. Over-extension and over-investment improve banks' bottom-line returns but represent a source of financial fragility for the economy. If a run occurs, banks have to fire-sale their asset collateral to industry outsiders (we call them "non-banks"), who don't have deep pockets. So, the price the assets fetch in those dislocated financial conditions will be below fundamental valuation. Banks individually see the private advantage of lending more – and borrowing more *short-term* – but overlook the wider price effect through which their private decisions to lend more can depress the liquidation price of assets and thus compromise all other banks' capacity to meet their deposit obligations. Precisely as in Stein (2012), this consideration makes the policy authority directionally conservative: less aggregate lending is better from this particular social perspective. But there is another perspective that the policy authority entertains. The authority also internalises that more investment (more lending) expands collective consumption, which is valuable under the macroeconomic leg of its mandate. In addition, if the distressed asset market could be bypassed and assets could be kept in the bank-intermediated sector where they are most productive, the economy would gain in efficiency. This is another advantage that individual banks don't consider in their calculus but is felt collectively and makes the policy authority less, not more conservative than the banks when evaluating the desired level of bank intermediation.

In our model, the policy authority can sideline markets and alter liquidity conditions to stimulate credit and investment without exposing the economy to a harsh unwind of over-investment in the event of a liquidity crisis. The policy authority can advance liquidity to the banks, and sustain a possible loss from the operation, because it has the power to tax. This obviously is what supports a budget authority making infusions of fresh resources into ailing banks. Should the banks eventually be unable to pay back the capital or liquidity injection, the lost cash will have to be recovered through general taxation. But think of a central bank as well, the main actor in the analysis that follows. A central bank doesn't possess a statutory right to tax. Yet, it can offset the losses associated with a measure taken today to assist banks by running down its balance sheet provisions, and then replenish the provisions by cancelling remittances to the public budget for years to come. This is a sort of deferred tax arrangement that can enable a beneficial, but potentially costly, monetary policy intervention. In our model, the tax is a non-distortionary source of resources to be used for depositor payouts in the event of a run. It conveniently replaces, in the equilibrium that we study, the very distortionary diversion of resources, from production to asset speculation, in which non-banks would engage if they had to absorb the fire sales from banks in the marketplace.

In what follows we think of the policy authority as the "central bank" and we study three equilibria in which the disintermediation mechanism is at play. The first equilibrium is what we refer to as a LOLR regime. Here, when the bad state hits, banks can turn to the central bank for borrowed liquidity rather than to the market for distressed assets. Heeding Bagehot's prescription, the central bank promises to lend freely to the banks, but on terms that mimic market conditions. Essentially, the collateral that banks are required to post to access the LOLR facility is subject to a haircut which reflects the punitive discount that would apply in the competitive market for distressed assets. We show that, despite the non-concessionary pricing of the loans to the banks, a LOLR equilibrium improves over the non-interventionist equilibrium (NI) with fire-sales studied by Stein (2012). Bank loans, investment and aggregate consumption are all bigger in LOLR than in NI. The reason is that, when a LOLR window replaces the market for bank assets as a source of emergency liquidity, the policy-induced disintermediation of the private asset market stimulates physical investment and income production in aggregate. But, because the disintermediation channel doesn't enter as a meaningful factor in the banks' choice process, in a LOLR equilibrium banks still don't borrow enough, there is a loan deficit and the economy suffers from under-investment. Note that our model is stigma-free, in that there is no information asymmetry or scope for signalling equilibria. What explains deficient intermediation in the model is simply a structural misalignment between banks' individual profit-maximising objectives and the policy authority's goal of enhancing collective welfare. The second equilibrium that we investigate shows that a "Credit Easing" regime (CE) does a better job of minimising deadweight costs and promoting welfare. Under CE, the central bank lends liberally as in LOLR, but calibrates the collateral haircut to encourage as much bank borrowing as it considers desirable from its welfare-maximising perspective. We prove that the terms and conditions of the loans to the banks can be made sufficiently attractive to bring private allocations into complete alignment with those that the central bank itself would select.

This result is not sufficiently general, however. When the level of investment put in place in the bank-intermediated part of the economy has (even a modest) positive externality on productivity in the non-bank sector, private and public choices diverge again. Even under the subsidised borrowing conditions offered by CE, lending and activity fall short of what the central bank considers part of an optimal allocation. Obviously, the banks overlook the cross-sector externality in production and disregard the fact that, by borrowing and lending more singularly, they collectively spur aggregate activity. We show that a "Quantitative Easing" (QE) regime – the third equilibrium we analyse – can reinstate the convergence of private choice outcomes and public goals. Here, the central bank offers to buy up a pre-set amount of the banks' assets. It's part of the QE arrangement that, if the banks choose not to sell that amount in the adverse contingency, the system reverts to LOLR. We prove that a QE regime can fully unlock the collective gains to be had in a social optimum even in the presence of production externalities.

Interestingly, we uncover a bank-intermediation side to the optimality of the Friedman rule which posits that it's optimal for a central bank to make liquidity available to the banks in amounts large enough so that the opportunity cost to holding it is zero. Goodfriend (2002), Keister *et al* (2008), Curdia and Woodford (2011), Reis (2013, 2023) and Vissing-Jørgensen (2023) generalise Friedman's (1969) early result to a world where the central bank pays interest on banks' cash reserves.[6] Similarly, in our model as well as – we shall see below – in the data, CE and QE regimes encode a policy of supplying liquidity at the lowest interest rate within the economy's rate spectrum. The reason for the Friedman rule's optimality in our context is that charging banks the minimum rate when lending or selling liquidity under CE or QE is a way for the central bank to compensate the banks for the otherwise unremunerated positive externality they bring to the system when borrowing more individually.

In the empirical sections of our paper we take our model predictions to the data. We use both bank- and loan-by-loan information to evaluate the connection between bank loan origination and the source of liquidity in the euro area. The euro area is an interesting environment to examine for our purposes. First, it closely conforms to the prototype of a bank-centred economy in which commercial banks dominate financial intermediation. In such an environment, banks' lending becomes a fundamental channel of monetary transmission. Second, the European Central Bank (ECB) has traditionally conducted monetary policy by lending to the banks through open-door regular refinancing operations. Arguably, this tradition of managing liquidity through loans rather than through purchases or sales of assets has helped normalise the act of borrowing liquidity from the central bank. So, the stigma factor should be minimal. Furthermore, following the great financial crisis, the ECB has experimented with a rich array of unconventional policies, including CE and QE. Our model delivers four testable predictions: (a) banks are generally reluctant to borrow from standard conventionally-priced backup facilities; (b) if such facilities are the only source of central bank liquidity, any shock that bolsters banks' preference for liquidity might urge them to temporarily increase their borrowings as a share of their assets, but they will not deploy the borrowed liquidity to maintain or expand their loan book. In fact, they will simultaneously shrink lending; (c) CE and QE – changing the nature of liquidity provision into something

[6] Reis (2023) and Vissing-Jørgensen (2023) challenge the optimality of the Friedman rule in a broader setting in which the purchase of assets necessary to saturate the liquidity market and satisfy the rule generate side costs that may entirely offset the benefits of driving the market rate to the floor of the rate corridor.

cheaper and more persistent – can nudge banks towards expanding their intermediation activity; (d) the extra credit spurred by CE and QE is productive: it's conducive to more investment and income.

Clearly, data are uninformative on the optimal scale of bank liquidity borrowing: we do not have a direct empirical measure for the borrowing (or loan) deficit that can conclusively validate (a). Yet, we find evidence that a key observable related to the quantity of bank borrowings, the fixing of overnight rate in the money market, signalled insufficient participation in liquidity-providing facilities at times in which the authorities' professed objective was to ensure ample reserve supply and generous credit flows. We view this evidence as lending indirect support to the hypothesis that the gap between the central bank's target for liquidity provision and banks' measured participation in liquidity operations can be positive and large. As for (b), the data are much more conclusive. Euro area bank-level and loan-by-loan data are consistent with the conjecture that, when banks tap a regular short-term backup liquidity window, they don't do so to support their loan book. We look at the response of bank lending *conditional* on a specific primitive shock that enhances banks' liquidity preference. In a regime resembling our LOLR prototype, a negative shock to the general economic conditions that increases the likelihood of a liquidity crunch down the line boosts banks' borrowings as a share of assets, but curtails loans. More generally, we find no statistical connection in the data between liquidity drawn from regular operations and loans to the non-financial private sector. By contrast, consistent with (c), we find a robust positive connection between loans and reserves borrowed under the Targeted Long-Term Refinancing Operations (TLTROs), a series of extraordinary, long-term loans from the ECB to the banks with a 3-year maturity at settlement, granted at a rate equal to or lower than the floor of the ECB's rate corridor. We detect an even firmer connection between loans and non-borrowed reserves, i.e. the liquidity that banks received as a result of the ECB's outright bond purchases under its QE programs. Overall, we find that, when it comes to drawing up plans for their core business operations, banks are not indifferent to the way in which they can source the liquidity that is necessary to execute those plans. Quantitatively, following a 1 percentage point change in liquidity reserves coming into the system through TLTROs or non-borrowed reserves generated through outright purchases, loan volumes increase by an amount between 1 per cent and 1.5 per cent of the initial stock after one year. Last, we examine firm-bank matching data and find that firms connected to banks with higher levels of reserves drawn from TLTROs or non-borrowed generate more investment, sales and employment. The extra loans due to CE and QE are productive.

Our paper sits at the intersection of three broad lines of research. One is the theory of asset liquidity, inefficient credit booms, fire sales and the fragility of banking. Here, our paper is most closely related to Stein (2012), from which we borrow the general contours of our model. We augment Stein's model with an activist policy function, and we study new equilibria which partly overturn his bank over-extension, over-investment result. In our model there is a need to foreclose fire-sales of banks' illiquid assets. These asset sales are wasteful because they attract speculation, which in turn divert resources from real project finance, a feature reminiscent of Shleifer and Vishny (1992, 1997). We prove that banks' failure to internalise this social objective leads to deficient bank intermediation and under-investment in aggregate. Shleifer and Vishny (2009), like us, study credit easing in a model of unstable banking. However, their definition of credit easing differs from ours and is closer to what we, in line with Gertler and Karadi (2010), refer to as a QE operation: an outright purchase of assets in distressed macroeconomic conditions. For us, a credit easing policy is a central bank program to lend liquidity to banks on concessionary terms. This allows us to assess how that policy scores relative to alternative forms of liquidity provision: standard, garden-variety refinancing of illiquid banks and outright purchases.

The second point of departure for our paper is the research tradition that investigates the effects of the supply of central bank liquidity on banks' intermediation activities. As mentioned above, this branch of research harks back to the insights gathered at the US Fed in the 1920s. After a long period of neglect, this tradition has recently been reinvigorated by Acharya and Rajan (2022) as well as Acharya *et al*. (2023). A nascent literature – see Rodnyansky and Darmouni (2017), Kandrac *et al* (2021), Christensen and Krogstrup (2019), Arce et al. (2020), Bianchi and Bigio (2022), Altavilla *et al* (2023b) and Diamond *et al* (2023) – has also explored the interconnections between reserve creation and bank loans. As Acharya and Rajan (2022), in particular, our paper embeds CE, QE and associated liquidity injections in a stylised model and tests the model with an empirical analysis. Unlike in their paper, however, in our model a financial-stability motivated concern for banks' incentive to seek excessive exposures sits together with, and can be weighed against, the policy authority's preoccupation for higher consumption, investment and credit. The disintermediation mechanism that we describe and the policy instruments that make the most of it justify placing a large weight on the macroeconomic objective and trying to forestall a scenario of credit under-provision. This objective prevails in our analysis. Our paper underscores the transmission-relevance of non-borrowed – as opposed to borrowed – reserves, an empirical regularity that has been known, but forgotten, for a while. Christiano and Eichenbaum (1992), Strongin (1995) or Bernanke and Mihov (1998), among others, have argued that the failure of earlier work to trace meaningful real effects of changes in monetary aggregates on interest rates and real variables was due in part to a lack of distinction between reserves injected at the discretion of the central bank and reserves drawn down at banks' initiative from a backup window to cover a temporary liquidity shortfall. By concentrating on non-borrowed reserves specifically, this literature showed that innovations in the money supply does have effects on interest rates and output. The main focus of this paper, loan creation and its connection with credit-easing and non-borrowed reserves, is the intermediate stage in that transmission chain.

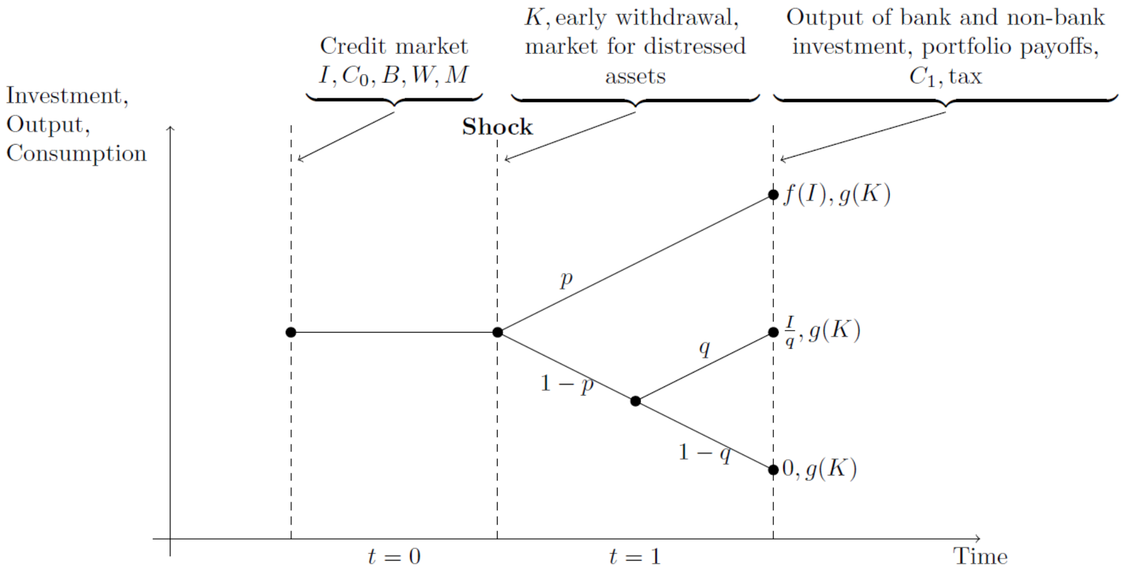
The third literature with which we make contact is the still burgeoning research on unconventional monetary policies. That literature has almost exclusively concentrated on the "interest rate channel" of central banks' balance sheet expansions and negative rate strategies. Gagnon *et al* (2011), Krishnamurthy and Vissing-Jørgensen (2011), Bernanke (2020) and Rostagno *et al* (2021a, 2021b), for example, point to large stimulative effects from unconventional policies coming through an induced compression of long-term yields. The injections of liquidity that came with those measures were, according to many studies, an incidental effect at best. Far from being secondary, in this paper we argue that the liquidity effect associated with CE and QE was probably dominant. True, these policies are combined in our model with the application of the Friedman rule, which slashes the policy rate to the floor of the range of interest rates. But in our setting the height of that range remains unaltered under CE or QE and a large share of the macroeconomic effects in fact come from the liquidity reassurance that CE and QE bring to the banks. It's that type of liquidity comfort that overcomes banks' reluctance to intermediate and gives critical loan support to the real economy.

The remainder of the paper is organised as follows. Section 2 lays out the model and derives its main results, with the proofs confined to Appendix 1. In Section 3, we discuss our model results in the broader context of the literature. In Section 4 we seek to validate our first testable hypothesis: the general reluctance of banks to borrow from conventional refinancing facilities. In Section 5 we document the main empirical findings of this paper, validating the second and third testable hypothesis that we extract from our model: banks don't use reserves borrowed in conventional refinancing operations for extending loans, whereas they do use reserves from credit easing facilities or from QE injections for lending. Section 6 concentrates on the real effects of loans when the lenders hold liquidity obtained from different sources and we find that the data support our fourth hypothesis. Finally, Section 7 concludes.

2. A model of bank reluctance

Following the lead of Stein (2012), we model a two-period economy with four sectors: households, bank-financed manufacturing ("banks" in short), non-bank-financed manufacturing ("non-banks"), and a policy authority, which we understand to be the central bank. Except for the central bank, there is a continuum of agents in each group, so markets are competitive. Households enter time-0 with an endowment of consumption goods equal to $\bar{\Upsilon}$ (see the timeline in Figure 1). At the beginning of time-0, they decide how much of $\bar{\Upsilon}$ to consume immediately, C(0), how much to invest in risky securities issued by banks (B) and non-banks (W), and how much to park in riskless, callable assets (M). We refer to the callable assets as "deposits", a type of inside money that only banks can supply. Households have linear preferences for time-0 and time-1 consumption, and they extract liquidity services from their deposit holdings. Their utility function is $U = C(0) + \beta C(1) + \gamma M$, which implies that households have an infinitely elastic supply of funds at time-0, as long as R, the real rate paid on securities, is equal to 1/β, the real rate R^M paid on deposits is equal to 1/(β + γ) < R, and $\bar{Y}$ ≥ C(0) + (B+W) + M, with C(0), B and W ≥ 0.7.

Figure 1. Timeline of the model



At the start of time-0, the credit market opens: banks and non-banks place their securities, *B* and *W*, respectively, and bank deposits, M/R^M— claims on a quantity of *M* in time-1 consumption goods discounted at the rate R^M – with households, and lend the proceeds from those asset placements onto entrepreneurs, who invest in their projects that eventually produce consumable output in time-1.[8] Banks and non-banks have their own separate pools of borrowing clients who have access to different technologies.[9] Those borrowing from a bank use a stochastic production function which, in a favourable state of the world that occurs with a probability *p < 1*, converts a quantity of time-0 investment *I* (with *I = B + M*) into *f(I)* units of

[7] In what follows we assume $\bar{Y}$ to be sufficiently large to satisfy the inequality conditions laid out in the main text in all of the three equilibria we study.

[8] At time-0, *M/R(M)* is a claim on *M* units of time-1 consumption, a claim that is actualised to time-0 at the real rate *R(M)* < *R*.

[9] We don't motivate the separation between the two pools of borrowers. There could be limitations to bank screening or monitoring which make certain categories of physical investment unpledgeable as collateral for a loan. Mechanically, we assume that those entrepreneurs/investors who borrow only from non-banks do so because they are not ready with a fully-articulated investment project by the time the time-zero credit market session ends, and therefore they cannot pledge collateral on time for a bank loan.

time-1 consumption goods (with $f(I) > I$, $f'(I) > 0$, $f''(I) < 0$). However, time-1 output has only an expected value of I in an adverse state of the world, which occurs with probability $1-p$. In the adverse state, there is a positive probability q that output at the end of time-1 may be as low as zero (see the contingency tree in Figure 1). The production technology of the sector borrowing from non-banks, instead, is deterministic and yields $g(K) + \alpha I$ (with $g(K) > K$, $g'(K) > 0$, $g''(K) < 0$) at the end of time-1 with certainty, for K units of physical investment made at the end of time-0. In what portion W is invested in the non-bank manufacturing technology or put to some other use ($K \leq W$) will become clear below. Notice that we allow for a one-way positive externality in production, running from the level of investment put in place in the bank-intermediated part of the economy to productivity in the other sector.[10] To simplify the algebra, we consolidate the banks and non-banks with their own borrowing entrepreneurs/investors, respectively, as if both lenders were using borrowed funds to invest directly into the two technologies described above.[11]

After the credit market session of time-0 shuts down, the state of the economy is revealed, i.e. it becomes clear whether the economy is in the good state in which the bank manufacturing technology is most productive (upper branch of the contingency tree in Figure 1), or it's going to evolve along a bad trajectory, where the bank manufacturing technology can yield at most I/q, and possibly nothing. As the state is revealed, non-banks decide where and how much to invest, and households have a last opportunity to decide whether to hold onto their deposit claims I the banks until the end of time-1, or cash out early. If they choose the latter option – fearful that the bad state might impair the banks' capacity to make good on their deposit obligations – the banks need to pledge or liquidate the M part of their immobilised assets to obtain the liquidity needed to pay out depositors. One way to do so is to take the selling side in a distressed-asset market session that opens as soon as the credit

[10] A straightforward way to interpret the positive contribution of I to production from the other sector is simply through the lenses of a canonical new-Keynesian accelerator effect. Rising investment in one sector implies increased sales and greater use of existing capacity in other parts of the economy and a more favourable business environment in general.

[11] To justify the bank/entrepreneurs consolidation one needs to assume that the entrepreneurs have no equity to fall back on to absorb losses in case the bad state hits, so the bank has no other option in those circumstances but seizing the borrower's physical assets and carrying over their liquidation.

market closes. The buyers in liquidation are the non-banks.[12] By virtue of their slow investment decision-making, after the credit-market session ends and the asset market session begins, non-banks still have liquid assets — the proceeds from previously placing *W* with the households — available to consider alternative investment options. In equilibrium, the non-banks won't take the buying side of the asset market unless the expected returns from investing in the assets unloaded by the banks equate the marginal returns from their own physical investment project, $g'(K)$. We lay out the non-banks' decision problem below. After households decide whether to stick to or cash in on their deposit balances ahead of time, and non-banks allocate their funds, the economy transitions to time-1.

We study three equilibria in which sight deposits can be made sufficiently safe even if the economy may travel along the adverse branches of the contingency tree shown in Figure 1. The three equilibria correspond to three alternative regimes in which the central bank takes upon itself the task of satisfying the liquidity needs in the face of a bank funding shock by intermediating resources across sectors and states of the world.

The LOLR regime

The first regime we consider is one in which the central bank announces at the start of time-0 that it stands ready to lend to the banks, at an interest rate $R^{LOLR} = [1 + (1-p)\frac{1-x}{x}]\, R^M < R$, an amount of claims to time-1 consumption goods sufficient to forestall a run. In a slight abuse of denomination, we refer to this arrangement as a lender-of-last-resort (LOLR) regime. In fact, it subsumes a system that regularly refinances illiquid banks through a standard, garden-variety lending facility on terms that are not too far from those available in the marketplace. Accordingly, we assume that, under this liquidity window, the banks' assets are subject to a $1-x$ haircut, which the central bank sets equal to $1-k$ $(0 \leq k \leq 1)$, the discount that those assets would suffer in liquidation relative to their full time-1 value, if the banks were forced to sell in a competitive market instead (see below). The central bank would thus guarantee a payment of *M* to the households at time-1 in exchange for the banks pledging $\frac{M}{x} > M$ at the end of time-0 in future assets. If *m* is the share of *I* that banks

[12] It's often the case that non-banks (e.g. hedge funds) end up absorbing distressed assets sold by banks facing liquidity strains. Think of the market for non-performing loans.

choose to fund with deposits in the credit market session of time-0, we assume the central bank's guarantee is sufficiently trustworthy to convince households to hang onto their deposits until time-1, provided two conditions are verified. First, the central bank should be able to invoke its indirect power to transfer resources across sectors and states of the world to demonstrate the wherewithal necessary to always deliver on its money guarantee. Second, $M = mIR^M$, the value of deposits issued by banks expressed in time-1 consumption goods, should be no bigger than xI, the after-haircut value of banks' time-1 expected gross returns from *I* in the bad state. In more compact notation, for a LOLR regime to be effective at eliminating fire-sales and providing a credible backing for the banks' deposit liabilities in this economy, the share of deposits in the overall bank funding structure has to respect a money-issuance constraint: $m \leq \frac{x}{R^M}$.[13] As we show below, the money-issuance constraint always binds with equality if $R > R^{LOLR}$, i.e. the cost of securities funding, *R*, to the banks is big enough to make deposit funding sufficiently attractive, even accounting for the extra losses the banks incur when forced to turn over assets to the central bank at a haircut to prevent a bank run. Note that, in the definition of R^{LOLR}, $\frac{1-x}{x}$ stands for the net loss to the bank from entering a LOLR loan contract with the central bank. Note also the sense in which the LOLR regime, where $\frac{1-x}{x} = \frac{1-k}{k}$ by construction, is non-concessionary. The price *x* is indeed punitive in that it shadows the price that those bank assets would fetch in a competitive market in financial distress.

In a LOLR regime banks maximise the following profit function with respect to *m* and *I*:

$$\mathbb{P}^B = pf(I) + (1-p)I - RI + mI(R - R^M) - (1-p)\frac{1-x}{x}mIR^M \tag{1}$$

subject to the money-issuance constraint, $m \leq \frac{x}{R^M}$. In eq. (1), R stands for the cost of funding the entire stock of bank investment, *I*, with securities remunerated at the higher real interest rate, *R*; $mI(R - R^M)$ is the gain from funding a share m of *I* by issuing cheaper deposits instead; $(1-p)\frac{1-x}{x}mIR^M$ measures the loss from having to over-collateralise the loan from the central bank in the bad state, a loss that is obviously increasing in the share of

[13] The constraint on the share of deposits in the banks' funding composition descends from imposing the inequality $mIR^M \leq xI$. See Stein (2012).

deposits in bank funding. From the first-order condition for m, it's easy to verify that $R > R^{LOLR} = [1 + (1 - p)\frac{1-x}{x}] R^M$ implies that the Lagrange multiplier associated with the money-issuance constraint is positive, $\eta > 0$, which in turn means that the money-issuance constraint has to bind in equilibrium, $m = \frac{x}{R^M}$. Combining the first order conditions for *m* and *I*, imposing the binding money-issuance constraint and the definition of R^{LOLR}, we obtain:

$$pf'(I) + (1 - p) - R = -\frac{x}{R^M}[R - R^{LOLR}] \quad (2)$$

From the above expression it is clear that the option of funding a share of their investments with deposits encourages banks to expand their assets *I*, and the quantity of bank credit as a result, beyond the level that they would choose in the absence of the deposit-taking opportunity. Notice that the right-hand side expression in eq. (2) is negative, while the left-hand side defines the condition that banks would seek to set to zero in search for an optimal level of *I* in a money-less economy.

The profit function of non-banks in a LOLR regime is:

$$\mathbb{P}^{NB} = g(W) + \alpha I - RW \quad (3)$$

where RW is the cost of funding *W* in the securities market and $K = W$, as in a LOLR set-up banks do not participate in the market for distressed-assets and non-banks have no other option than invest in their deterministic technology.

The economics of disintermediation, whereby the central bank creates collective gains by circumventing and hollowing out market intermediation in the sourcing of emergency liquidity, can be fully appreciated by comparing eq. (3) with the expression that the non-bank profit function would take on in a Stein-type, non-interventionist regime (NI). In NI, where banks are forced to monetise their immobilised assets by selling to non-banks if a bank run occurs, the non-bank profit function has the following form: $\mathbb{P}^{NB}_{NI} = pg(W) + (1 - p)\, g(W - M\,) + \alpha I - RW + (1 - p)\frac{M}{k}$. This alternative expression takes into account that, in NI, in case the bad state hits, non-banks are able to earn a return from purchasing an amount *M* from the banks at the dislocated market price $k \leq 1$ per unit of their fundamental value: this is the last term in $\mathbb{P}^{NB}_{NI}$, expressed in probability-weighted form and in terms of time-1 consumption goods. However, that diversion of funds by non-banks in NI comes at the deadweight cost of curbed real investment in the non-bank sector, and ultimately lower time-

1 output. The second term in the expression shows that effective investment in the non-bank technology is what is left of W after some borrowed funds worth M are absorbed into funding the purchase of an equal amount of bank distressed assets, which the banks offload in the market: production in the bad state is only $g(W - M\ )$ in NI. As we shall see below, the policy authority ignores the "speculative" private gain accruing to the non-banks, $\frac{M}{k}$, but detects and seeks to minimise the loss to aggregate production, $g(W) - g(W - M\ )$. This justifies an interventionist regime, such as LOLR, that sidelines the market. Note also the sense in which LOLR closely conforms to the Bagehot's description of sound central bank lending in a liquidity crisis, which should be unsparing in volumes but forthcoming only at a penalty price. Indeed, the pricing of liquidity assistance in LOLR relies on $\mathbb{P}_{NI}^{NB}$: the first-order condition for M using the $\mathbb{P}_{NI}^{NB}$ profit specification pins down the discount that would be applied to the banks' assets in the competitive market, $k = \frac{1}{g'(W-M\ )}$. Given that the terms of the policy authority's loan to the banks in a LOLR regime are non-concessionary, with $x = k$, that condition for k also nails down the degree of over-collateralisation under the LOLR facility.

The policy Lagrangean looks as follows:[14]

$$\begin{aligned}\mathbb{L}^{LOLR} = &\left\{pf(I) + (1-p)I - RI + (R - R^M)mI - (1-p)\frac{1-x}{x}mIR^M \quad\right\}\\ &+ \{g(W)\ + \alpha I - RW\} + (1-p)\frac{mIR^M}{x}\\ &- (1-p)T^{LOLR} - \mu^{LOLR}[mIR^M - \tau(I + g(W)\ + \alpha I)]\\ &- \eta^{LOLR}\left[m - \frac{x}{R^M}\right]\end{aligned} \tag{4}$$

[14] Recall that, from households' optimality problem, $\frac{1}{R^M} = \gamma + \beta$, which implies that $\gamma = \frac{1}{R^M} + \frac{1}{R}$. (4) derives from the primitive expression for households' intertemporal consumption, $\left\{\bar{Y} - (I + W)R - M\frac{R}{R^M}\right\} + \{(I + W)R + M + \gamma RM + \mathbb{P}^B + \mathbb{P}^{NB}\}\ \ - (1-p)T^{LOLR}$, which the policy authority seeks to optimise with respect to *m* and *I.* In this latter expression, all quantities are defined in terms of time-1 consumption goods. Notice that the terms in the first parenthesis sum up to households' time-zero consumption, C(0), expressed in time-1 consumption goods; the second parenthesis corresponds to households' time-1 consumption, C(1), comprehensive of profit payouts (positive or negative) from banks and non-banks, plus the utility value of holding a monetary claim to M consumption goods; and T^{LOLR} is the lump-sum tax described below. Collecting terms, and using (1) and (3) to substitute out $\mathbb{P}^B + \mathbb{P}^{NB}$, the above expression defines the policy Lagrangean in (4).

where $x = \frac{1}{g'(W-M)}$, $M = mIR^M$; $(1-p)mIR^M = (1-p)T^{LOLR}$; and T^{LOLR} is a lump-sum tax raised by the policy authority in the bad state on the households' final income. A number of features of eq. (4) are noteworthy. First, $(1-p)\left[\frac{1-x}{x}mIR^M + \frac{1}{x}mIR^M\right] = (1-p)mIR^M$ is an important condition. What it means is that aggregate welfare is not affected by the distribution of losses and gains resulting from the LOLR transaction in the bad state: the over-collateralisation loss to the banks is offset by the associated gain accruing to the central bank. So, all that matters for aggregate utility is the residual $(1-p)mIR^M$ contingent claim to time-1 consumption resources that needs to be paid out with certainty to the depositors. This is the only form of resource intermediation that survives in (4). Second, the central bank's role in a LOLR contract is precisely that of intermediating this residual state-contingent claim on mIR^M, using its power to facilitate a transfer of resources, $(1-p)T^{LOLR}$, from profits to the depositors and thereby make good on the monetary pledge embodied in the LOLR contract with the banks. To make that pledge credible, such a contingent "tax" can't be larger than the maximum taxable amount that can be collected on the aggregate expected gross production in a bad state, $\tau(I + g(W) + \alpha I)$. This justifies the presence of the term attached to the Lagrange multiplier, $\mu^{LOLR} \geq 0$. Third, similar to Lorenzoni (2008) and Hart and Zingales (2013), we are interested in a constrained-efficient, second-best optimum. In looking for a solution to eq. (4), the central bank respects the same money-issuance constraint faced by the banks, which explains the last term in eq. (4) attached to the Lagrange multiplier, $\eta^{LOLR} \geq 0$. The unconstrained first-best for society may well contemplate dismantling the monetary friction altogether, but the central bank treats that friction as a structural, unmodifiable mechanism of how the economy works, on a par with the technologies used in the bank and non-bank sectors.

A couple of preliminary observations help to narrow down the relevant solution to (4). First, from the first-order condition for *m* we see that the two constraints can't be both slack if $I > 0$, i.e. if bank investment contributes positively to aggregate consumption. Second, assuming the money-issuance constraint binds, with $M = mIR^M = xI$, since $x \leq 1$, it's straightforward to verify from the term multiplying μ^{LOLR} that there exists a sufficiently high value of τ for which the tax constraint will not be binding. We therefore solve the policy

Lagrangean for $\eta^{LOLR} > 0$, $\mu^{LOLR} = 0$ assuming τ is "sufficiently big" to make the tax constraint non-binding when the money-issuance constraint binds. From the first-order condition for *I* we obtain:

$$\begin{aligned} pf'(I) + (1-p) - R \\ = -\left[\frac{\lambda}{g'(W - mIR^M)R^M}[R - R^M] + \alpha\right] \\ - \eta^{LOLR}\left[\lambda m \frac{g''(W - mIR^M)}{g'(W - mIR^M)^2}\right] \end{aligned} \quad (5)$$

where, again, in searching for an optimum, the central bank – unlike the banks – internalises the connection between *x* and the price that the bank assets would command in the time-0 distressed-asset market, if market liquidation were the only opportunity open to the banks to recover some asset value in the face of a run on deposits. A comparison between eq. (5) and eq. (2) supports the following proposition:

PROPOSITION 1: Denote as I^* the level of investment that banks choose when solving for the privately-optimal competitive allocation in a LOLR regime and as M^* the level of borrowing at the LOLR facility in case of a deposit run; denote also as I^{LOLR} the socially optimal level of investment chosen by the central bank in the same regime and as M^{LOLR} the quantity of borrowing under the LOLR facility consistent with I^{LOLR}. For $\alpha = 0$, and under plausible parameterisations of the model – including Stein's (2012) calibration – $I^{LOLR} > I^*$ and $M^{LOLR} > M^*$.

COROLLARY 1: Imagine that, at the beginning of time-0 while the credit market session is still open, a macroeconomic shock intervenes to perturb a LOLR equilibrium in the making: the probability attached to the good state, p, falls to $p' < p$, detracting from the upside payoff from bank investments and simultaneously increasing the likelihood of a liquidity accident. Then, in the post-shock LOLR equilibrium: (1) banks will borrow more as a share of their assets than they would have in the absence of the shock, i.e. m^* is larger, but will invest less, i.e I^* is smaller; (2) the lending and monetary financing gaps, $I^{LOLR} - I^*$ and $M^{LOLR} - M^*$, both increase i.e. banks' reluctance to intermediate becomes more acute.

COROLLARY 2: Imagine that, at the beginning of time-0 while the credit market session is still open, a macroeconomic shock drives α from 0 to $\alpha' > 0$. Then, while both I^{LOLR} and

M^{LOLR} increase in response, I^* and M^* remain constant. In other words, banks' reluctance to intermediate increase if assessed against the norm set by the social optimum.

The results described in the two corollaries are interesting. A shock that increases the probability of a liquidity accident pushes banks to borrow more as a share of their assets, but the borrowing doesn't go hand in hand with loan creation: quite the opposite. This offers the first of our testable hypotheses, as in the data it's not hard to trace the dynamic response of borrowing and lending to an identified shock that boost banks' liquidity preferences. The second corollary questions the banking system's readiness to support structural shifts that, if exploited, can enhance the economy's productive potential. Think of the positive network complementarities emphasised by the recent report on "The future of European competitiveness" (Draghi, 2024). Our model implies that an economy that sees production complementarities strengthened by new developments, which also raise the desired level of intermediation as a result, doesn't find in banks sufficiently supportive intermediaries. For a proof of Proposition 1 and Corollaries 1 and 2, see Appendix 1, which also experiments with a numerical calibration of the model that mirrors that proposed in Stein (2012).

In summary, as $I^{NI} < I^*$, we confirm Stein's insight that the money friction may bring the economy to a larger quantity of bank investment (and credit) than is desirable from a welfare perspective: banks have a tendency to over-expand their balance sheets and create the conditions for over-investment. However, we prove that that result does not hold universally, but only within a NI setting where there exists no other way to back deposits than for the banks to commit to sell down a commensurate portion of their assets in the competitive market if faced by a liquidity crisis.[15] In a LOLR regime, where the central bank can liquefy illiquid assets, banks are *reluctant* to borrow – $M^* < M^{LOLR}$ – and lend on the borrowed liquidity when judged against the central bank's own standards, and the problem is one of *under-* not *over-investment*: $I^* < I^{LOLR}$. Where does this discrepancy between our result and that of Stein (2012) stem from? The central bank in a LOLR regime is aware of the mechanism that, if banks originate more credit and money, the pressure for liquidations in the asset

[15] It's interesting that allowing for a very mild measure of production externality (with $\alpha = 0.005$) in an otherwise pure non-interventionist Stein-like environment would suffice to make $I^{NI} > I^*$.

market would become more acute in a bad state and, as a consequence, the discount to the expected value of the assets sold in that market, $1-k$, or pledged under a LOLR facility, $1-x$, would increase. This is the same type of adverse pecuniary externality identified by Stein (2012) and Lorenzoni (2008): individual banks do not internalise the externality when selecting *I*, but a social optimiser sees that, because of the externality, the banks' atomistic decisions influence the other banks' preferred level of investment through the money-issuance constraint. And it's in the interest of social welfare to minimise this pricing effect. As in Stein's description of the decision problem solved by the social optimiser, in (5) the internalisation of this pricing effect by the central bank is visible in the dependency of *x* on $g'(W-mIR^M)$. And, indeed, all the terms that incorporate that dependency term in (5) *per se* tend to push I^{LOLR} below I^*. However, in our LOLR regime, unlike in Stein's NI, the central bank can force the non-banks to invest the entire amount of borrowed funds *W* into their production technology. While non-banks are indifferent between investing resources in their own technology or in the banks' assets as long as $k=\frac{1}{g'(W-mIR^M)}$, from an aggregate welfare perspective foreclosing the possibility for non-banks to divert part of their funds to the bank asset market is preferable, as it boosts aggregate consumption in all circumstances. This consideration works toward making I^{LOLR} larger, and higher than I^*, as the associated larger quantity of $M^{LOLR}=mI^{LOLR}R^M$ would not detract from gross production in a bad state.[16]

The Credit Easing regime

The central bank can do a better job of promoting investment, credit and social welfare than under a LOLR system. Changing the conditions of the loan to the banks, it can nudge banks toward borrowing more and funding more projects. One option is to move away from a LOLR governance, where liquidity is made available to banks in case of need on penalty

[16] Stein's social optimum problem boils down to the following condition, which is the counterpart to our eq. (4): $(4b)\quad pf'(I)+(1-p)-R=-\frac{k}{R^M}\left[R-\left(1+(1-p)\frac{1-k}{k}\right)R^M\right]-\eta^{NI}\left[m\frac{g''(W-mIR^M)}{g'(W-mIR^M)^2}\right]$, where $k=\frac{1}{g'(W-mIR^M)}$ and $\eta^{NI}>0$ is the Lagrange multiplier attached to the money-issuance constraint in Stein's non-interventionist environment. A comparison between (4b) and (2), the condition defining the private allocations in our (and in Stein's) environment, demonstrates Stein's over-investment result. The general-equilibrium adverse price effect of banks' over-investment is what lies at the heart of the pecuniary externality studied by Lorenzoni (2008) and Stein (2012). In their models, by reducing aggregate investment ex ante a planner can reduce the size of the asset sales in the bad state.

terms, towards a lending facility where loans are priced attractively. We refer to this alternative governance system as the "Credit Easing" (CE) regime. Here, the central bank is not constrained by $x = k = \frac{1}{g'(W - mIR^M)}$ when setting the interest rate, $R^{CE} = [1 + (1-p)\frac{1-x}{x}]\,R^M$, on its loans to the banks. In a CE regime, the asset discount for the loan collateralisation, $1 - x$, which uniquely pins down R^{CE}, is itself treated as a choice variable in the policy selection process.

While in CE the profit functions maximised by the banks and non-banks mirror precisely their analogues in LOLR, namely eq. (1) and eq. (3), respectively, with a binding money-issuance constraint, $m = \frac{x}{R^M}$, the Lagrangean of the policy decision in CE looks slightly different:

$$\begin{aligned} \mathbb{L}^{CE} = {} & \{pf(I) + (1-p)I - RI + (R - R^M)mI\} + \{g(W) + \alpha I - RW\} \\ & + (1-p)mIR^M \\ & - (1-p)T^{CE} - \mu^{CE}[mIR^M - \tau(I + g(W) + \alpha I)] \\ & - \eta^{CE}\left[m - \frac{x}{R^M}\right] - \mu_x^{CE}[x-1] \end{aligned} \tag{6}$$

Where, again, $(1-p)mIR^M = (1-p)T^{CE}$. After imposing the familiar condition, $(1-p)\left[\frac{1-x}{x}mIR^M + \frac{1}{x}mIR^M\right] = (1-p)mIR^M$, which holds also in LOLR, the difference between (6) and (4) boils down to the last term of (6), the constraint that the optimal *x* should only satisfy $x \leq 1$. From the first-order condition relative to *x* we derive the conclusion that either this latter constraint and the money-issuance constraint are both binding or they are both slack, i.e. either $\eta^{CE}, \mu_x^{CE} > 0$, or $\eta^{CE} = \mu_x^{CE} = 0$. Imagine the latter equality holds. Then, from the first-order condition for *m,* it must be that $\mu^{CE} > 0$ for the level of investment to be positive.[17] But the latter inequality condition, together with $\eta^{CE} = 0$ and $m < \frac{x}{R^M}$, also imply that $mIR^M < xI$. For any $x \leq 1$, and for τ "big enough", this would contradict the condition that $\mu^{CE} > 0$. Therefore, a consistent solution to eq. (6) should entail $\eta^{CE}, \mu_x^{CE} > 0$ and $\mu^{CE} = 0$, i.e. $x = 1$, $m = \frac{1}{R^M}$ and a slack tax constraint. Under this parameterisation, $x = 1$ implies

[17] The first-order conditions with respect to *x* and *m* are, respectively: $\eta^{CE}\frac{\lambda}{R^M} = \mu_x^{CE}$, and $(R - R^M)I = \mu^{CE}IR^M + \eta^{CE}$.

$R^{CE} = R^M$. In other words, the interest rate applied in the lending facility is equal to the bank deposit rate. Furthermore, the set of first-order conditions becomes recursive, with the first-order condition for *W* pinning down *W* as a function of *R,* and the first-order condition for *I* also making bank investment a function of the model's parameters. The following two propositions follow:

PROPOSITION 2: Denote as I^{**} the level of investment that banks choose when solving for the privately-optimal competitive allocation in a CE regime and as M^{**} the corresponding level of bank borrowings in the CE facility; denote also as I^{CE} the socially optimal level of investment chosen by the central bank in the same regime and as M^{CE} the corresponding desired quantity of borrowings in the CE facility. For $\alpha = 0$, the private competitive allocations coincide with those prescribed by the social optimum. In particular, $I^{CE} = I^{**} > I^{LOLR}$, and $M^{CE} = M^{**} > M^{LOLR}$.

PROPOSITION 3: When $\alpha > 0$, $I^{CE} > I^{**} > I^{LOLR}$ and $M^{CE} > M^{**} > M^{LOLR}$.

See Appendix 1 for proofs and a numerical example.

In other words, by making liquidity assistance at an interest rate equal to the "lower bound" rate paid on deposits, R^M, the central bank in a CE regime can always encourage participation in the lending operations, and boost credit, investment and output beyond the levels that would be observed in a LOLR regime. If market failures are not too pervasive, CE is successful in bringing private allocations into complete alignment with those prescribed by the social optimum. However, when investment in the bank-intermediated sector has positive externalities on output in the other sector, the privately-chosen levels of borrowings and investment fall short of the central bank's targets.

Quantitative Easing

In the presence of production externalities, a "Quantitative Easing" (QE) program can push the economy to the CE optimum. Under QE, the central bank can induce banks to expand their borrowings from M^{**} to M^{CE} and use M^{CE} to finance as much as I^{CE} in new projects. It can do so by offering to purchase a pre-set amount of bank assets M^{QE} equal to M^{CE} – expressed in time-1 consumption goods – in the event of a bank run at a price $P^{QE} \geq 1$. A bank can decide to sell or keep ownership of the assets. If the bank decides not to sell M^{CE}, it can still be granted access to a LOLR facility in the event of a bank run. Will the banks accept to participate in QE and sell? The following proposition establishes that 'he banks' decision to play by, or shun the QE rules of engagement depends on a comparison between their expected profits in QE relative to their expected profits in LOLR, the regime they would fall back on if they decided to invest I^{LOLR} and issue M^{LOLR} in deposits instead.

PROPOSITION 4: Denote as I^{***} the privately-optimal level of investment selected by the banks in a QE regime, as P^{QE} the unit price at which the central bank is ready to purchase the banks' assets in a crisis, and as $I^{QE} = I^{CE}$ and $M^{QE} = M^{CE}$ the central bank's targets for investment and deposits, respectively, under QE. For $\alpha > 0$ not too far from zero and under plausible parameterisations of the model, $I^{***} = I^{QE}$ even with $P^{QE} = 1$, which reproduces the valuation of asset collateral under CE.

See Appendix 1 for a proof and a numerical example. In our model, QE is essentially the ultimate enabler of a credit easing agenda. A CE regime is successful in bringing that agenda to full fruition only insofar as misalignments between private and policy objectives are confined to the price externality and the gleaning of potential gains from disintermediation that we describe above. But, with externalities in production, subsidised lending under CE is not powerful enough to overcome banks' parsimonious borrowing propensities and push investment and lending to match the credit easing targets. In order to achieve those targets, the central bank needs to become the master of its own balance sheet. Under CE, banks decide how much to borrow and borrowings determine the size of the central bank's monetary assets. In QE, the size of the balance sheet becomes an intermediate target for the central bank, in the service of its credit easing and macroeconomic objectives.

Note that these model mechanics have a strong real-world counterpart. In late 2014, after implementing a first round of TLTROs with disappointing take-up, the ECB decided to set a target for the size of its monetary policy assets and implement the target through asset purchases. Quoting from the ECB's November 2014 post-meeting statement: "*Together with the series of TLTROs to be conducted until June 2016, [our] asset purchases will have a sizeable impact on our balance sheet, which is expected to move towards the dimensions it had at the beginning of 2012*." See also Rostagno *et al*. (2021a).

3. Discussion on liquidity and intermediation

Assuming that our approach has some merit in explaining what appears to be a pervasive, yet understudied phenomenon, our key to interpreting banks' reluctance to intermediate can nonetheless be interrogated from at least three angles. First, how can a real model – where either contracts are expressed in units of consumption goods or prices are perfectly flexible – be utilised to evaluate competing monetary policy frameworks? The answer lies in the fact that, in the model, banks and non-banks are blind to the systemic implications of their private choices and to the collective gains that could be reaped if their choices were different. This is a real market failure that can be addressed by a central bank, even in conditions in which prices are not sticky and monetary policy has no impact on nominal incomes. The key mechanism is the tight connection between credit and investment / production / incomes. The central bank can boost bank and non-bank credit, and hence real incomes, by intermediating real resources across time and states of the world. In future research, it will be interesting to investigate how these frictions interact with nominal rigidities, the canonical friction encoded in monetary models of the business cycle. Our conjecture is that, so long as credit is linked to investment and the central bank has an interest in output and consumption, the main implications of our analysis would carry through to a monetary model where sticky prices are added as an extra friction.

Second, the absence of bank reserves in our model of banking can be queried. In earlier work (Altavilla *et al,* 2023c), we suggested two mechanisms for how liquidity connects with loan creation. Either commercial banks first decide how many loans they want to extend, and then borrow reserves from the central bank to support those loans; or reserves are first injected by the central bank, and then commercial banks react to this inflow of liquid assets by creating new loans. The former representation of the mechanism essentially follows the "endogenous money" hypothesis.[18] The latter mechanism can be understood as the

[18] Goodhart and others at the Bank of England (see McLeay *et al* 2014) have been passionate proponents of the "endogenous money" doctrine. In this tradition, banks extend credit, creating deposits in the process, and look for the reserves later. Standing at the end of the causal queue, the central bank cannot force money on the economy: it merely supplies reserves on demand.

transmission of a monetary shock in an "exogenous money" world.[19] We don't model a fractional-reserve banking system here, so reserves are not a defined object in our model. But the mechanics and implications of our model conform with, and in fact help reconcile the "endogenous" and "exogenous" money hypotheses. In the model, in tune with the former view, banks' demand for liquidity derives from their primitive lending plans. But, consistent with the latter view, the terms and conditions on which central bank liquidity is expected to be made available in the wake of a liquidity squeeze are the ultimate drivers of the decision to originate credit. In the end, the model encapsulates a shared feature of the two views: the more loans on the books of banks, the more pressing the need for them to have liquidity available to build a sufficient buffer against deposit outflows that a larger issuance of loans will bring with itself. What we miss in our model analysis is the duration aspect of the connection between reserve availability and loans – an aspect we heavily stressed in Altavilla *et al* (2023c). CE and QE can enhance the bank lending channel partly because they are both seen as providing a permanent liquidity means to service the mobile type of deposits that are the by-product of an act of extending bank credit. So long as these central bank operations are expected to cause a stable expansion in the central bank's assets, the commercial bank can make the educated guess that the system will have a lot of central bank reserves for a long time, and that it's "safe" enough to expand credit. By contrast, liquidity borrowed in a short-term refinancing facility is essentially seen as backup funds. Drawing funds from a safety valve should help only in case of unexpected liquidity tensions. These tensions can always happen ex post. But a prudent bank scales and profiles its lending plans so that the probability of such liquidity risks hitting in the loan execution phase is driven to zero ex ante. A permanent inventory of cash is perceived as more conducive to business expansion than a call option that

[19] In a fractional-reserve banking system, the total amount of loans that commercial banks extend (and the commercial bank money that they create) is equal to a multiple of the amount of reserve injections. The multiple is a reciprocal function of the minimum reserve ratio imposed by the central bank, and the amount of currency and reserves in excess of the reserve requirement that banks target for their everyday activities as a proportion of their deposit base. The notion is that the banks will expand the amount it lends up to the point at which the store of reserves it owns is equal to a desired prudent fraction of the total amount of loans extended. That fraction is a ratio below unity, which makes the multiplier bigger than one. If banks lend out close to the maximum allowed by the multiplier, an initial injection of high-powered money into the banking system gets multiplied through bank lending and inside money creation.

the central bank may offer in the form of a lending facility that supplies funds on demand if internal cash resources become insufficient. Banks are therefore disinclined to tap a contingency source of short-term funding to plug a structural deficit of liquidity, which helps rationalise banks' reluctance to transform money drawn from that source into credit. We leave the modelling of this reserve duration effect for future work.

Third, loan activity is strongly procyclical. In our model there are no regulatory rigidities, information asymmetries or borrower-related moral hazard incentives, three factors that in theoretical work are often seen as meaningful sources of a cyclical pattern in bank credit. Yet, the result described above in Corollary 1 can be generalised. Perturbations to p, of either sign, can set off swings in bank credit in the model that look much like sentiment-driven procyclical booms and busts of the type surveyed by Schularick and Taylor (2012) among many others.

4. Banks' reluctance to borrow in the data

In this Section and in the following two we look at the data through the prism of our four testable hypotheses. Here, we ask whether the data can support the conjecture that banks are generally reluctant to borrow cash from conventionally-priced regular liquidity facilities. Clearly, the data are uninformative on the optimal scale of borrowing in central bank operations. Yet, empirical work can provide circumstantial evidence on whether observables related to the quantity of bank borrowings, such as the fixing of overnight rates in the money market, may signal insufficient participation in liquidity-providing facilities, especially over times in which the authorities' professed objective was to ensure ample reserve supply and generous credit creation. We mention above one post-debt-crisis episode in the history of the euro area in which banks' demand for central bank liquidity fell short of the ECB's cash supply desiderata. Here, we formalise that descriptive analysis. In addition, we report on the ECB's stance on the scarce volumes of liquidity that the banks were drawing from its facility at a juncture when credit was faltering.

We concentrate on the two years from mid-2012 to mid-2014 that run between the euro area sovereign debt crisis and the ECB's implementation of large-scale CE and QE policies.[20] That interim period is particularly informative about a regime in which banks are given a standing option to borrow liquidity on terms that resemble market conditions: what we refer to in Section 3 as a LOLR regime. Specifically, banks in the euro area had the option to borrow unlimited amounts of liquidity from the ECB under its Main Refinancing Operations (MRO), conducting liquidity auctions on a weekly basis, and the 3-month Long-Term Refinancing Operations (LTRO). The traditional variable-rate-tender auctions to allot liquidity in the two facilities had been replaced in October 2008 by a "fixed-rate full allotment" mechanism, which assigned liquidity in unrestricted amounts in exchange for eligible collateral.

As it turns out, between mid-2012 and mid-2014, banks not only largely reimbursed the liquidity they had drawn from extraordinary long-term liquidity operations launched earlier in the crisis years,[21] but they were also shunning the opportunity to tap the regular facilities even as reserves were shrinking. Lack of borrowing – despite widespread funding uncertainty – produced a dearth of liquidity systemwide, which in turn led to rising volatility in the overnight interest rates as the money market equilibrium made an abrupt transition from abundant to scarce liquidity conditions.

Lopez-Salido and Vissing-Jorgensen (2023), Lagos and Navarro (2023) and Afonso *et al* (2023), among many others, have found that the demand for central bank reserves has a shape and location that are time-varying. Given the limited time span of the data we use for this analysis, we do not estimate a specific parametric shape of the demand curve.[22] Instead, using the approach suggested by Fan (1992), we fit a non-parametric curve on the data linking

[20] The announcement of the ECB's Outright Monetary Transactions (OMT) programme in August and September 2012 led to a significant easing of tensions in euro area sovereign debt markets. In June 2014, the ECB announced the first series of TLTRO as well as preparatory work for its ABS purchase programme (ABSPP), the first subcomponent of the expanded Asset Purchase Programme (APP).

[21] Following the financial crisis, the ECB had occasionally offered exceptionally long-term refinancing operations with maturities of more than 12 months, through which banks had obtained significant amounts of excess liquidity. Banks borrowed substantial amounts of excess liquidity under these facilities, peaking at more than 2% of total banking assets in the first quarter of 2012. When these long-term refinancing operations matured, however, banks reduced their excess reserve holdings substantially, to less than 0.5% in the first half of 2014, rather than replacing them with liquidity drawn from the standard refinancing facilities.

[22] We greatly appreciate discussions with and input by Rogier Quaedvlieg on this point.

the overnight rate – as a spread over the deposit facility rate, the floor of the ECB's rate corridor – to the amount of excess liquidity – as a share of total banking assets.[23] Figure 2 shows the estimated demand schedule, distinguishing between the period of shrinking excess liquidity (the red line, which uses a sample period with no outstanding extraordinary long-term operations) and periods in which excess liquidity was stable or increasing (the blue line, using a sample period with outstanding extraordinary long-term operations). The picture inspires two observations. The option to borrow freely at the MROs and 3-month LTROs does not appear to have prevented the overnight rate to become unstable and unpredictable, if compared with its behaviour in periods of ample liquidity. Specifically, the red-curve association between the overnight rate and the quantity of reserves is more dispersed compared to that along the blue curve: the confidence bands around the estimate are twice as wide during the period of declining excess liquidity even for equally scarce aggregate liquidity conditions. Secondly, the overnight rate occasionally even pierced through the line marked by the lending rate applied under the MROs. Despite liquidity conditions becoming overly strained, banks individually did not have an incentive to borrow nearly as much as necessary to infuse more reserves into the system and alleviate the stress.[24]

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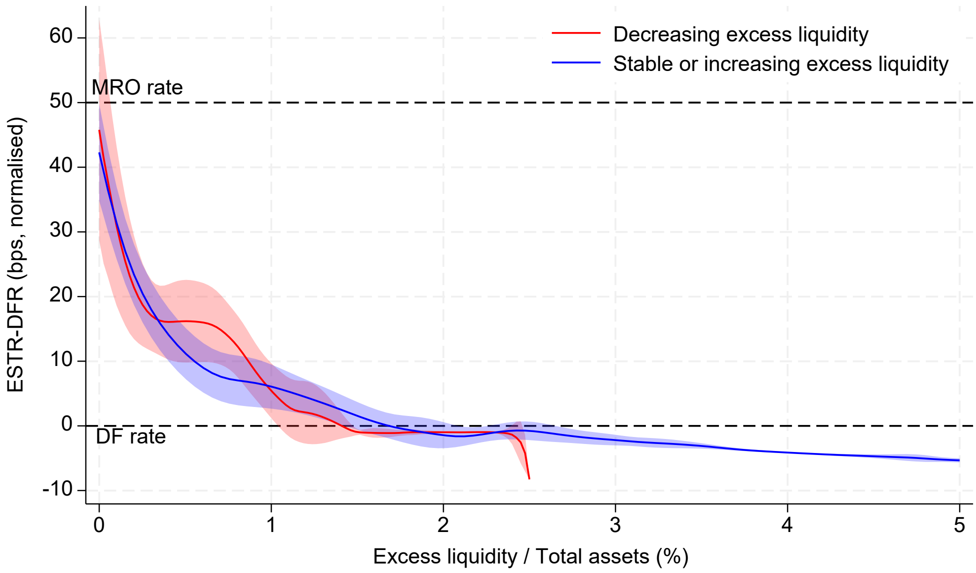
[23] Our modelling approach is more in line with Afonso *et al*. (2023), who do not attempt to determine the full reserve demand curve but focus on local elasticities to reserve shocks, than papers such as Lopez-Salido and Vissing Jorgensen (2023) or Lagos and Navarro (2023), who derive fully specified parameters of the reserve demand curve in the US.

[24] This holds true also when applying the parametric form of Lopez-Salido and Vissing-Jorgensen (2023) to euro area data, who fit a log-linear relationship between the overnight rate spread on banks' excess liquidity holdings as well as their deposit base. We find that, prior to the financial crisis, the slope coefficient in a demand curve for reserves estimated separately for every maintenance period over the past 20 years – to account for dynamic shifts in the relationship – was negative, and subject to very little uncertainty. During periods of declining excess liquidity, however, the reserve demand curve became very steep, but its precise size and even sign varied substantially over short horizons. Given the elevated uncertainty about banks' reserve demand during the interim period, it is not surprising that also the volatility of short-term interest rates was particularly pronounced during this time compared to the more predictable regimes prior to the financial crisis and following the large-scale injection of non-borrowed reserves and reserves created through CE programs.

Figure 2: Non-parametric estimate of the reserve demand curve during periods of stable and decreasing excess liquidity



Note: The chart shows the fitted values from a non-parametric estimate of the relationship between the ESTR-DFR spread (normalised to a 50bps corridor widths to account for changes in the spread between the policy rates over time) and the banking system's excess liquidity holdings (defined as a ratio of total assets and adjusted for the averaging of minimum reserve requirements over a maintenance period), distinguishing between the sample period from June to December 2010 and January 2013 to December 2014 as the "decreasing excess liquidity regime" (red line), and the remainder of the sample period as the "stable or increasing excess liquidity regime" (blue line). The overall sample begins in October 2008, when the ECB's liquidity provision in regular refinancing operations changed to a policy of full allotment. The estimate follows the procedure by Fan (1992). The range of the excess liquidity variable is divided into a grid of 100 equally-sized bins. Using the observations in each bin, the ESTR-DFR spread is regressed on the excess liquidity holdings with quartic kernel weights. Specifically, the weights at the excess liquidity / total assets bin m_i for the observation m_j is given by $w_{m_i} = \begin{cases} \frac{15}{16}\left(1-\left(\frac{m_i-m_j}{\lambda}\right)^2\right)^2 & \text{if } |m_i - m_j| < \lambda \\ 0 & \text{otherwise} \end{cases}$. The bandwidth parameter λ is set to 0.66% in the "stable or increasing excess liquidity" regime and to 0.33% in the "decreasing excess liquidity regime" to account for the fact that the support of the excess liquidity variable ranges from 0-5% in the former and from 0-2.5% in the latter subsample. Shaded areas indicate a 99% confidence interval.

The ECB castigated banks' behaviour harshly. ECB president Mario Draghi described banks' reluctance to borrow central bank liquidity as ill-founded "*statements of virility*", arguing that the extraordinary LTRO funds offered at the end of 2011 and at the beginning of 2012 were intended to "*[address] the quantitative shortages and liquidity constraints of certain parts of the euro area financial and banking system*" (Draghi, 2012). The ECB's chief economist noted that, amidst an ongoing destruction of central bank liquidity, "*borrowing conditions were being tightened at precisely the time when the economy needed support*" (Praet, 2016). The causal chain that, according to the ECB, linked bank borrowing, liquidity availability in the system and overnight rate volatility was made clear in a statement stressing that "*renewed tensions in short-term money markets"* warranted a policy response *"to the extent that these are propagated to the medium-term curve, in particular in an environment of receding excess liquidity in the euro area*" (Draghi, 2014).

Our model offers a key to interpreting this dissonance between banks' collective choices and the central bank's aspirations: an unremunerated externality. This type of frictions make it unlikely that banks will bid at the weekly facility, the MRO, for amounts that, when combined, will necessarily sum up to an aggregate stock of liquidity that can help execute the central bank's macroeconomic goals. If a bank borrows more, other banks benefit because there will be more liquidity and the cost of borrowing liquidity in the market will be lower. But the bank is not compensated for the benefit it brings to the system, it only bears the individual cost. Adopting the classifications of our model, the individual cost is lower in LOLR – a regime centred around facilities such as the MROs and the 3-month LTROs – than in NI, but remains substantial. So, the bank will borrow less than is desirable from an aggregate welfare perspective.

5 Bank lending and liquidity provision

In this Section we consult the data to test the two main hypotheses that we derive from our model results. First, there is no positive correlation between banks' loans and an increase in their borrowings under a conventionally-priced standard refinancing facility. Anything that intensifies banks' preference for liquidity might urge banks to temporarily increase their borrowings as a share of their assets. But they will not deploy the borrowed liquidity to maintain or expand their loan book. In fact, they will simultaneously shrink lending. Second, CE and QE – changing the nature of liquidity provision into something cheaper and more persistent – can nudge banks towards expanding their intermediation activity.

Before turning to the econometrics, we conduct some descriptive analysis of the data. Bank level analysis is based on lending volumes and other individual bank balance sheet items, including security holdings, that are retrieved from a proprietary dataset, the Individual Balance Sheet Indicators (IBSI). IBSI reports asset and liability items of 345 banks resident in the euro area from July 2007 to July 2024. We integrate the bank-level information from IBSI with supervisory statistics – on regulatory capital ratios, non-performing loans and return on assets – and with confidential data on access of individual banks to central bank liquidity operations and minimum reserve requirements from an additional dataset on liquidity management. The cross-sectional distribution over time of the main bank-level variables, including the ones on liquidity, is reported in Appendix 2.

Our second source of data is AnaCredit. This dataset is a harmonized credit registry that includes loan-by-loan, bank-firm matched information on banks' credit exposures to all firms in the euro area with a reporting threshold €25,000. From Anacredit, we obtain monthly information on bank/firm relationship over the period from September 2018 to July 2024. Overall, the sample consists of a panel of 2,386,620 bank-firm relations. Table 1 presents the summary statistics for the main variables used in the Anacredit-based part of our empirical analysis.

Table 1. Summary statistics

Variable name	Units	Obs.	Mean	St.Dev.
Loan	log(EUR mln)	53,258,310	-2.84	2.28
Credit lines	log(EUR mln)	8,790,698	-1.51	1.70
Excess liquidity	%	53,258,310	9.47	7.66
Non-borrowed reserves	%	52,986,444	4.37	6.13
Borrowed reserves	%	53,258,310	0.07	0.44
TLTRO	%	53,258,310	6.74	7.55
Secutiry holdings	%	53,258,310	7.33	8.78
Return on assets (ROA)	%	53,258,310	0.30	0.59
Non-performing loans (NPL)	%	53,258,310	3.58	2.85

Note: loans (credit lines) are defined as logarithm of outstanding amounts (in EUR million) of loans (credit lines) between a bank and a firm in a given month. Excess liquidity is the ratio of excess liquidity (current account + deposit facility – minimum reserve requirements) over assets. Borrowed reserves are the ratio of borrowed reserve (MRO+LTRO) over main assets. Non-borrowed reserves are the ratio of non-borrowed reserves (excess liquidity-MRO-LTRO-TLTRO) over assets. The variable TLTRO represents the ratio of funds borrowed under TLTROs over assets.

5.1 Bank lending in a LOLR regime

We first seek to validate the conjecture that, when banks tap a back-up source of central bank liquidity, they don't do so to support their loan book. We look at the response of bank lending *conditional* on a specific primitive shock that enhances banks' liquidity preference. Consistent with Corollary 1, in a regime resembling LOLR we expect a negative shock to the general economic conditions to boost banks' borrowings as a share of assets but to curtail loans.

We use a Bayesian vector autoregression (BVAR) model in a panel-data setting, i.e. a Panel-BVAR model.[25] Letting the vector of non-policy variables for bank "*i*" operating in country "*j*" at time "*t*" be $y_{i,j,t}$, and the vector policy variables be $z_{i,jt}$, the panel VAR takes the following form:

$$\begin{pmatrix} I & 0 \\ A_{0,yz} & I \end{pmatrix}\begin{pmatrix} z_{i,j,t} \\ y_{i,j,t} \end{pmatrix} = A(L)\begin{pmatrix} z_{i,j,t-1} \\ y_{i,j,t-1} \end{pmatrix} + \begin{pmatrix} e_{i,j,t} \\ u_{i,j,t} \end{pmatrix} \quad (7)$$

$z_{i,j,t}$ includes the overnight interest rate as a proxy of the policy rate, and the excess liquidity acquired under the regular refinancing operations, the weekly MROs and the 3-month LTROs as a share of assets measured at bank level; $y_{i,j,t}$ includes lending growth to firms, the common equity tier 1 capital ratio, the ratio of security holdings over assets, the inflation rate measured by the harmonised index of consumer prices (HICP) and industrial production. The inflation rate and industrial production are used also to proxy for business cycle conditions and therefore absorb time-varying credit demand factors.

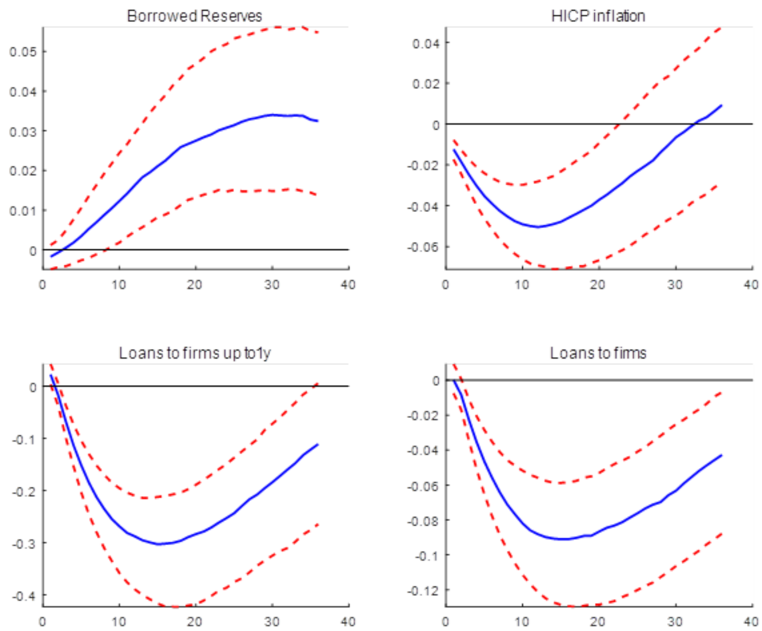
The first exercise simulates the effect of a temporary shock depressing industrial production (IP) by 1 percentage point, as a proxy of the state of the macroeconomy keeping the policy rate unchanged over the simulation horizon. The results obtained collapsing the data at time level over the sample July 2007-July 2024, using for each time period the median of the cross-sectional distribution of banks, and then simulate the BVAR model are reported in Figure 3. As conjectured, in response to the shock, banks increase their borrowings in regular refinancing operations as a share of assets, but at the same time they restrain credit supply.

We now move to a second exercise where the cross-section of banks is used in full by estimating the model in equation 1. The estimation and simulation procedures follow Altavilla *et al*. (2020) and exploit both the cross-section and the time series dimension of the data. Notice that when using the panel version of the BVAR model, while the policy interest rate is set at the euro area level, borrowed reserves vary at the bank level. Using actual borrowed liquidity of individual banks has clear advantages as it allows us to track the lending response of a shock that varies uniformly in the cross-section of banks. In other words, the bank-specific

[25] Panel VAR models (Holtz-Eakin, Newey, and Rosen 1988) have been used in multiple applications in macroeconomic and finance (Canova and Ciccarelli, 2013).

effect of the shock will likely also reflect heterogeneity in the holdings of non-borrowed reserves across banks.

Figure 3: The impact of a negative shock in industrial production

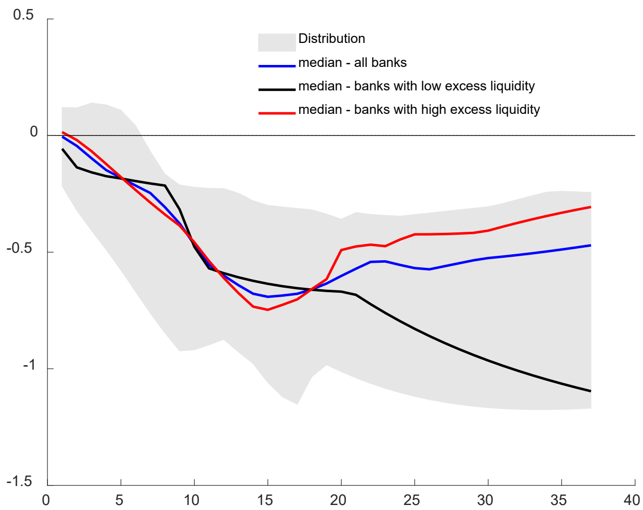


Notes: The figure presents the response of the variables to an unanticipated temporary shock that decreases industrial production by 1 pp and leaves the policy rate unchanged over the entire simulation horizon. The solid line is the median, the red dotted lines represent the 16th and 84th percentiles of the posterior distribution.

Figure 4 shows the distribution of the responses of the growth rate of lending to firms for all banks in the sample, assuming a 1 percentage point temporary decrease in the industrial production and keeping the policy rate unchanged over the simulation horizon. The figure illustrates the results for a BVAR specification with a 12-month lag structure. In addition, both charts report the distribution of the lending growth response for all the banks in the sample (shaded grey area) together with the median response across all banks (blue line), the median response of the subset of banks with higher excess liquidity as a share of assets (red line) and banks with lower excess liquidity (black line). The threshold used to define the two subsamples of banks with higher and lower excess liquidity is the 75th percentile of the cross-sectional distribution measured in June 2023. We have experimented with different dates, but the results remain barely unchanged.

Two main findings emerge. First, individual banks respond to adverse shocks—regardless of their balance sheet characteristics or country of operation—by increasing their holdings of non-borrowed reserves and reducing their lending activity. Second, the decline in lending is more pronounced for banks with lower excess liquidity relative to their assets.

Figure 4: Lending growth response to a negative shock in industrial production



Notes: the figure presents the cross-sectional distribution of median responses of lending growth of the 345 banks in the sample to a 1 percentage point decrease in industrial production for all banks (grey area). During the simulation horizon the policy rate is kept unchanged. The chart also shows the median response of two group of banks: the banks with higher ratio of excess liquidity (current account + deposit facility – minimum reserve requirements) over assets (red line) and the banks with lower ratio of excess liquidity over assets (black line). The x-axis depicts months after the initial shock. The shaded area represents the 16th and 84th percentiles of the posterior median distribution.

5.2 Regimes of liquidity provision and bank lending

Here, we generalise and extend the results documented in Section 5.1. We use panel-data methods to generalise the finding that backup liquidity is uncorrelated with bank credit, and we ask how liquidity injections connect to credit origination in two alternative regimes of liquidity provision: CE and QE. We estimate impulse response functions for individual banks' corporate loan growth to changes in the ratio of three liquidity measures over assets using local projection models (Jordà, 2005). The three empirical measures of liquidity that we use in our econometric analysis are: "borrowed reserves", i.e. liquidity drawn from MROs and 3-month LTROs; "credit easing reserves", i.e. liquidity drawn from TLTROs; "non-borrowed reserves", i.e. liquidity obtained from QE injections. The local projection model specification that we utilise is the following:

$$\Delta L_{i,t+h} = \alpha_{i,h} + \beta_h \Delta NBR_{i,t} + \delta_h \Delta BR_{i,t} + \lambda_h \Delta \mathrm{CER}_{i,t} + \Gamma_{\mathrm{h}} X_{i,t-1} + \epsilon_{i,t+h} \quad for\ h = 1, \dots, 24 \qquad [8]$$

where $\Delta L_{i,t+h}$ is the change in loans to firms by bank *i* between time *t* and *t + h*, and $\Delta BR_{i,t}$, $\Delta CER_{i,t}$ and $\Delta NBR_{i,t}$ represent the change in the ratio of borrowed reserves (BR), credit easing reserves (CER) and non-borrowed reserves (NBR), respectively, over assets. More precisely, $\Delta BR_{i,t}$ is computed as the change in the sum of funds borrowed in regular open market refinancing operations – the weekly MROs and the 3-month LTROs – divided by bank assets; $\Delta CER_{i,t}$ is the ratio of TLTRO funds, over assets; and the variable $\Delta NBR_{i,t}$ is defined as the difference, at the bank level, between excess liquidity and the sum of funds borrowed in all central-bank liquidity operations (MRO, LTRO, and TLTRO) as a share of bank assets. The coefficients β_h, δ_h, and $\lambda_h$measure the response of banks' loan growth to a change in those three measures of liquidity up to time *t + h*.

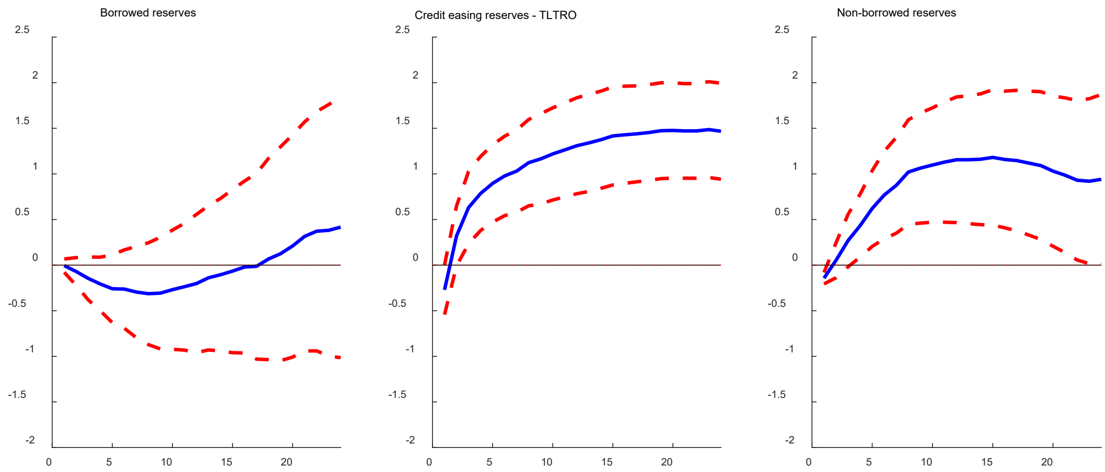
The model also includes a vector of lagged observable characteristics at the bank level. Specifically, the vector $X_{i,t-1}$ includes the non-performing loan (NPL) ratio, the return on assets (ROA), and the share of government and corporate securities in bank assets. We control for loan demand conditions by (1) including a proxy for loan demand obtained from the replies of individual banks participating in the euro area Bank Lending Survey (BLS); and (2) including bank fixed effects ($\alpha_{i,h}$) to control for the bank-specific unobserved heterogeneity related to banks' business models and any other time-invariant characteristics.[26] The latter variables help disentangle credit supply from credit demand factors and ultimately shed light on the transmission of central bank reserve shocks to the lending conditions via banks. Note also that the bonds-to-assets ratio helps discriminate whether any positive connection between loan creation and reserves might be due to reserves causing an expansion of loans or simply to a correlation between the two variables in times of QE. In fact, it could be argued that, by pushing down long-term rates and stimulating growth as a result, QE could have fostered credit regardless of any reserve

[26] The results presented in this section are robust to the inclusion of country and country*time fixed effects.

balances being created in the process. The control is a good proxy for the exposure of individual bank balance sheet to central bank asset purchase programmes (see Andreeva and García-Posada, 2021; Altavilla *et al*. 2022, Bottero *et al*. 2022), so any residual positive correlation between reserves and loans should be interpreted as a causal relationship running from the former to the latter. The sample covers the period between August 2007 and July 2024.

Figure 5 shows the response of banks' loan growth up to time *t + h* to an expansion in our three reserve measures at time *t*. The figure reports the coefficient β_h, δ_h, and λ_h, with their respective confidence intervals for each horizon *h* with standard errors clustered at the country*time and bank level. Confirming our prior results, we find that a 1pp change in borrowed reserves does not lead to any significant effect on lending. In fact, the dynamic correlation is weakly negative. By contrast, following an equally-sized increase in non-borrowed reserves at the initiative of the central bank, loan volumes increase by about 1% after one year. The same increase in credit easing reserves have similar effect.

Figure 5: Response of bank loans after a 1pp increase in liquidity provision



Note: The figure reports the cumulated response of banks' loan growth up to time *t+h* to an increase in TLTRO, non-borrowed and borrowed reserves ratio at time t. The solid line are retrieved from the coefficients β_h, δ_h, and λ_h from the regression $\Delta L_{i,t+h} = \alpha_{i,h} + \beta_h \Delta NBR_{i,t} + \delta_h \Delta BR_{i,t} + \lambda_h \Delta \mathrm{CER}_{i,t} + \Gamma_\mathrm{h} X_{i,t-1} + \epsilon_{i,t+h}$, $h = 1, \dots, 24$. $\Delta L_{i,t+h}$ is the cumulated change in loans to firms of bank *i* between *t* and *t + h*; the variable $\Delta NBR_{i,t}$ and $\Delta BR_{i,t}$ represents the change in the ratio of borrowed and non-borrowed reserves over assets. $\Delta \mathrm{CER}_{i,t}$ is instead the ratio of credit easing reserves, i.e. TLTRO funds, over assets. $X_{i,t-1}$ includes the non-performing loan ratio, the return on assets, bank-specific credit demand conditions from the BLS, the share of government of government and corporate securities in the bank's assets, the level of excess liquidity over asses and the share of deposit of assets. The dashed lines report the 95% confidence intervals for each horizon *h* with standard errors clustered at the country*time and bank level.

Having established the basic correlation results, we move towards a more causal analysis by checking if non-random selection of banks introduces a bias into our empirical analysis. Specifically, non-random selection into treatment could be associated with the fact that banks' participation in refinancing operations is demand-driven. In other words, as there is no proper randomization, the participation in liquidity operations (i.e., the treatment) is not independent of the expected outcomes (i.e., lending behaviour). This is because both the amount borrowed by banks in central bank operations and the volume of their lending to the private sector can mutually depend on unobserved characteristics. In particular, the impact of a change in liquidity may be biased downward if the banks that borrowed more from the refinancing operations had worse lending prospects. Cleanly identifying the impact of liquidity reserves on banks' lending activity would therefore require a quasi-random assignment of reserves to individual institutions. While policy measures in the euro area related to the remuneration of excess reserves allow such an identification approach at particular points in time (see Altavilla *et al*, 2023b), the approach does not allow to distinguish the composition of liquidity into the three categories of reserves that we define.

In order to alleviate concerns on potential endogeneity issues related to banks' participation in ECB liquidity operations in our setting, we therefore augment the local projection model outlined in (2) to include instrumental variables for both borrowed and non-borrowed reserves. The local projection instrumental variable (LP-IV) approach can be used to estimate dynamic causal effects (Jordà, 2005; Jordà et al. 2015 and 2020; Plagborg-Møller and Wolf, 2021). The instrument for the three sources of liquidity is a "shift-share" Bartik (1991) type of instrument (see also Goldsmith-Pinkham, Sorkin and Swift, 2020) and is based on the idea that, while a single bank can control its own demand, it cannot affect the amount of liquidity in the system as this is decided by the central bank. The instrument for borrowed reserves ($Z_{i,t}^{BR}$) takes the following form:

$$Z_{i,t}^{BR} = ln\left(\frac{BR_t}{BR_{t-3}}\right) \times Share_{i,t}^{BR}. \quad [9]$$

The instruments for credit easing reserves and non-borrowed reserves are calculated in the same way, i.e. substituting in equation [9] BR_t with CER_t and BR_t, respectively. Equation [9] makes it clear that this shift-share instrument aims to reduce endogeneity concerns by focusing on the more exogenous component of the treatment variation of interest. Notice that the first term, i.e. the *shift*, represents the quarterly growth rate of the specific reserve aggregate of reference, a quantity that an individual bank cannot influence. The second term, i.e. the *share*, is instead linked to the share of each bank's borrowed reserves over the total reserves. To ensure that this second term is less depended on specific events, we take the 12 months average as $\frac{1}{12}\sum_{k=1}^{12} BR_{i,t-k}$. The instrument used in the analysis is similar to the one also employed by Acharya *et al*. (2023). For credit easing, we use two additional methods to mitigate the endogeneity issues related to banks' participation in central bank liquidity operations. The first, and our preferred one, uses high-frequency information on the bank-specific funding cost relief associated to TLTRO announcements (Altavilla *et al* 2023a; Barbiero *et al* 2022).[27] The second method uses as instrument the time-varying borrowing allowances for banks participating in TLTROs (Benetton and Fantino, 2021; Da Silva *et al* 2021). This is the maximum amount of refinancing that the banks could draw from the facility, exogenously set as a share of each bank eligible lending, i.e. lending to firms and lending to household for consumer credit, excluding housing loans.[28] The results obtained using our preferred identification method are reported in Figure 6.

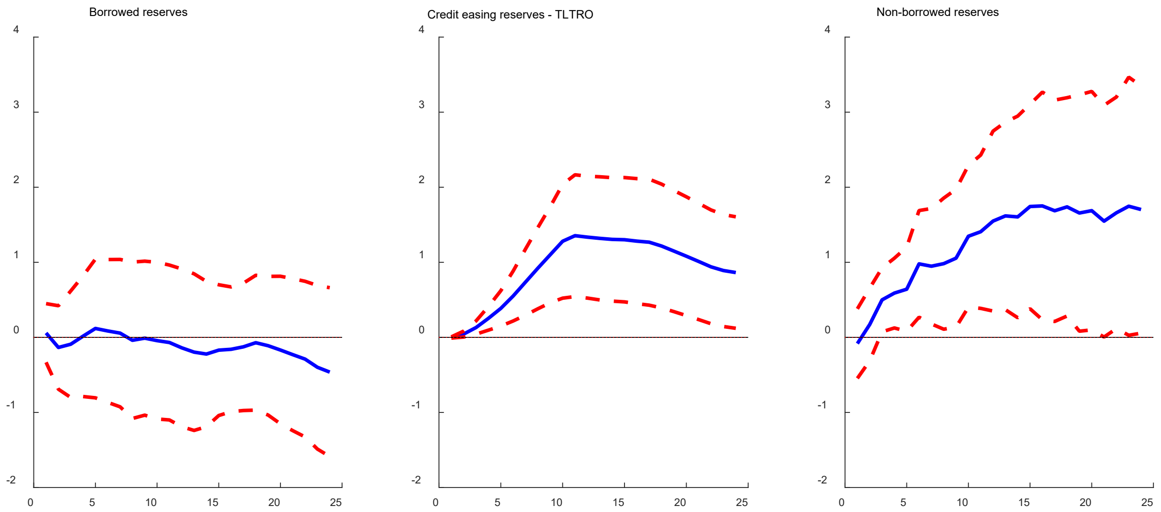
The picture inspires three observations. First, the main results obtained above still hold through: changes in borrowed reserves do not affect bank lending, while borrowing under TLTROs or reserve injections through QE significantly stimulate loan origination. Interestingly, a change in liquidity drawn from TLTROs has a similar impact on lending as a change in non-borrowed reserves. Second, the general pattern of the impulse response is very similar to the one estimated without instrumental variables. Third, the size of the estimated impact of an

[27] As shown in Altavilla *et al* (2023a) this identification strategy has several advantages. First, it relies on a market-based measure of bank funding cost rather than on banks' participation in the operations, which being a bank decision is endogenous to banks' characteristics and to their expected lending behaviour. Second, the high frequency identification plausibly rule out reverse causality and endogeneity problems associated, among other issues, to the influence of banks' pre-existing characteristics. Third, the change in individual bank bond yields likely reflects the actual improvement of bank funding conditions due to the announced changes in the policy.

[28] We use direct information on TLTRO uptake and borrowing allowances from the confidential templates submitted by banks as part of their reporting obligations to participate in the refinancing operations. This information allows us to measure exactly how much each bank was entitled to borrow under the various TLTROs and how much it borrowed. Results using this method (not reported, but available upon request) are similar, although somewhat stronger, than the one reported in figure 15.

increase in NBR is larger than the one estimated without instruments: following a 1percentage point increase in non-borrowed reserve, bank lending increases and reach a peak impact of about 1.5 percentage point after one year and a half.

Figure 6: Response of bank loans after a 1pp increase in liquidity provision



Note: The figure reports the cumulated response of banks' loan growth to a drop in TLTRO, non-borrowed and borrowed reserves ratio. The solid line are retrieved from the coefficients β_h, δ_h, and λ_h from the regression $\Delta L_{i,t+h} = \alpha_{i,h} + \beta_h \Delta NBR_{i,t} + \delta_h \Delta BR_{i,t} + \lambda_h \Delta \mathrm{CER}_{i,t} + \Gamma_\mathrm{h} X_{i,t-1} + \epsilon_{i,t+h}$, $h = 1, \dots, 24$. $\Delta L_{i,t+h}$ is the cumulated change in loans to firms of bank *i* between *t* and *t + h*; the variable $\Delta NBR_{i,t}$ and $\Delta BR_{i,t}$ represents the change in the ratio of borrowed and non-borrowed reserves over assets. $\Delta \mathrm{CER}_{i,t}$ is instead the ratio of credit easing reserves, i.e. TLTRO funds, over assets. The instrument for the borrowed reserves is $Z_{i,t}^{BR} = ln\left(\frac{BR_t}{BR_{t-3}}\right) \times Share_{i,t}^{BR}$. The instrument for the non-borrowed reserves is calculated in a similar way. The variable $\Delta CER_{i,t}$ is instrumented with the high frequency changes in bank-specific bond yields around TLTRO announcements. Additional lagged observable characteristics at the bank level are included in the vector $X_{i,t-1}$. These variables are the non-performing loan (NPL) ratio, the return on assets (ROA), bank-specific credit demand conditions from the BLS, the share of government of government and corporate securities in the bank's assets, the level of excess liquidity over asses and the share of deposit of assets. The dashed lines report the 95% confidence intervals for each horizon *h* with standard errors clustered at the country*time and bank level.

5.3 What do loan-level data say?

The availability of a rather long time series for each bank variable in our analysis has enabled us to examine the dynamic effects of liquidity injections over time using techniques borrowed and adapted from time-series econometrics. By employing fixed effects in a bank-level panel, we can control for unobservable characteristics that are not accounted for by other covariates in the model. For instance, in our specification, bank-specific fixed effects absorb time-invariant characteristics at the bank level, which could otherwise bias the estimation results.

Thus, any bank balance sheet characteristics that remain constant throughout the estimation period are effectively captured by these fixed effects.

There are, however, unobserved characteristics at bank and firm level that *do* vary over time and cannot be fully controlled for when using bank-level data. Therefore, we complement the empirical analysis documented above using granular information from AnaCredit, which affords taking a more detailed look at drivers of lending dynamics. We run a series of alternative model specifications that progressively saturate the model using different fixed effects. More explicitly, the model specifications include: i) firm fixed effects, to absorb the influence of time-invariant and firm-specific effects; ii) time fixed effects, to control for time-varying factors; and iii) firm*time fixed effects, to control for firm-level loan demand and other time-varying firm-level effects. This fixed-effects specification absorbs factors such as the demand for bank debt in a particular firm, at a particular time and uses only data for firms that have multiple bank relationships (Khwaja and Mian, 2008). The idea behind the exercise is that, if a firm has multiple lending relationships, when a bank decreases its credit exposure to this firm while other banks leave their exposure to the same firm unchanged or even increase their exposure, this is a change in loan supply that does not depend on credit demand conditions (which are controlled for by including the firm*time fixed effects). We also use an alternative specification to demand control based on industry–location–size–time fixed effects (Degryse et al. 2019) that identifies time-varying bank credit supply using both single- and multiple-bank firm relationships. The results are reported in Table 2.

Importantly, when moving from bank- to loan-level data, the two main results obtained above hold. First, in line with our model predictions, the effect of a change in borrowed liquidity on credit supply is negative, although not statistically different from zero. This result also holds when controlling for demand conditions (column 8). Second, an increase in credit easing or non-borrowed reserves leads to a significant expansion in credit supply. A 1 per cent increase in credit easing reserves (TLTRO) over assets is associated with an increase in loan supply that varies from 0.6 per cent to 1 per cent. This is consistent across model specifications, also when controlling for demand conditions at individual firm level (column 6), and once more lends support to the results of the model. The effect of an increase in non-borrowed reserves is comparable in magnitude to that of credit easing: a 1% increase in the ratio of non-borrowed reserves to assets is associated with approximately a 1% increase in credit supply. However, in more saturated specifications, such as those in columns 4 to 6, the impact of non-borrowed reserves is consistently larger than the effect observed for an increase in TLTRO reserves.

Table 2: Loan growth and liquidity provision – Bank-firm panel

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta BR_{b,t-1}$	-0.591	0.213	0.570	0.528	0.200	-0.103
	(0.575)	(0.685)	(0.642)	(0.567)	(0.673)	(0.417)
$\Delta CER_{b,t-1}$	0.441***	1.114***	1.147***	0.674***	0.822***	0.577***
	(0.131)	(0.256)	(0.238)	(0.201)	(0.240)	(0.126)
$\Delta NBR_{b,t-1}$	1.537***	1.027***	1.069***	0.773***	0.990***	0.889***
	(0.276)	(0.319)	(0.296)	(0.221)	(0.316)	(0.191)
Share of securities held$_{b,t-1}$	0.311	0.650**	0.442	0.0385	0.687**	0.312
	(0.325)	(0.314)	(0.293)	(0.257)	(0.329)	(0.295)
$ROA_{b,t-1}$	16.55***	12.36***	11.74***	6.009***	10.72***	6.418***
	(1.927)	(1.785)	(1.635)	(1.067)	(1.720)	(1.054)
$NPL_{b,t-1}$	-0.428	-1.910***	-1.718***	-0.869***	-1.914***	-1.318***
	(0.343)	(0.385)	(0.352)	(0.318)	(0.382)	(0.310)
Fixed effects:						
Bank	Yes	Yes	Yes	Yes	Yes	Yes
Time	-	Yes	Yes	-	Yes	-
ILS	-	-	Yes	-	-	-
ILS*Time	-	-	-	Yes	-	-
Firm	-	-	-	-	Yes	-
Firm*Time	-	-	-	-	-	Yes
Observations	63085929	63085929	63085928	63084924	63007675	40985546
R-squared	0.006	0.008	0.151	0.372	0.384	0.753

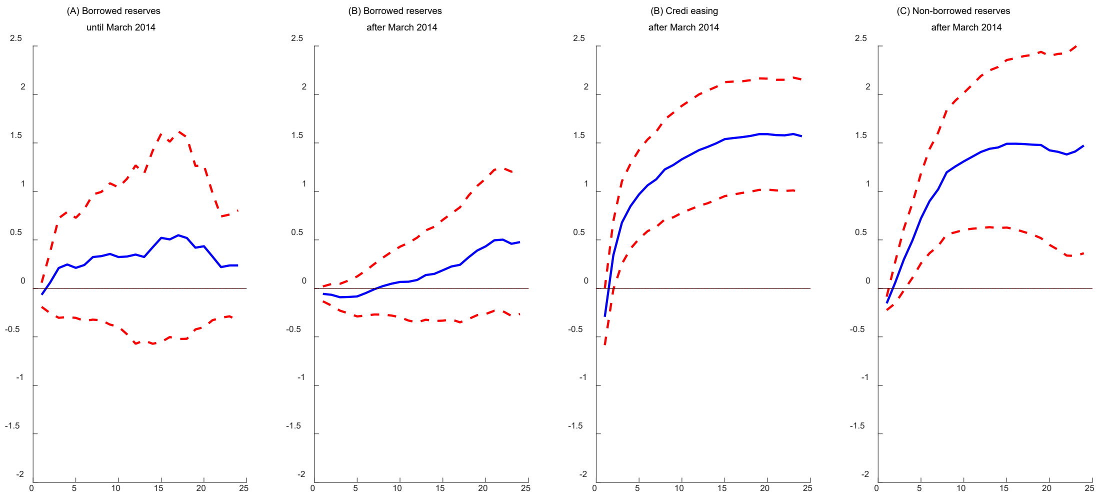
Note: the dependent variable is the annual growth rate of loans to firms f by bank i at time t. The model includes other control variables. Borrowed reserves (BR) represent the change in borrowed reserves (MRO+LTRO) over main assets. Non-borrowed reserves (NBR) are the change in non-borrowed reserves (excess liquidity-MRO-LTRO-TLTRO) over main assets. Credit easing reserves is the change in the TLTRO liquidity over main assets. The model includes share of security held, ROA and NPL ratio as additional control variables as well as the set of fixed effects as reported in the table. ILS stands for industry-location-size fixed effects. Standard errors are clustered at bank and time level. * p<.1, ** p<.05, *** p<.01.

5.5 Robustness exercises

This section includes additional analysis that complements and enhances the robustness of the main findings documented above. First, we restrict the sample to a period where non-borrowed reserves were practically zero. Second, we check whether the ECB's implementation of a negative rate policy (NIRP) might have introduced an incentive for banks to lend that can act as a confounding factor in our estimates and bias our results.[29] Third, we measure the effect of TLTROs on lending and then assess whether the results obtained above change when NIRP and QE is included in the estimation model.

In a first exercise, we assess the impact of borrowed reserves on lending in a sample restricted to July 2007-March 2014, i.e. over a period prior to the ECB's announcement of its outright purchase programme. Over this restricted sample period, the main sources of excess liquidity creation were the regular standard operations, MROs and 3-month LTROs, occasionally complemented with longer-term unconditional lending operations.[30]

Figure 7: Response of bank loans before and after the non-standard monetary measures



Note: The figure reports the cumulated response of banks' loan growth to an increase in borrowed, credit easing and non-borrowed reserves ratio at time t. We control for lagged observable characteristics at the bank level $X_{i,t-1}$, including the non-performing loans (NPL) ratio, the return on assets (ROA), the share of government and corporate securities in the bank's assets, bank-specific credit demand conditions from the BLS, and bank fixed effects $\alpha_{i,h}$. In addition to the benchmark specification, we also control for the level of excess liquidity over asses and the share of deposit of assets. The shaded areas report the 95% confidence intervals for each horizon *h* with standard errors clustered at the country*time and bank level.

[29] The European Central Bank introduced its negative interest rate policy (NIRP) in June 2014 when it decided to cut for the first time its deposit facility rate to -0.1%. The deposit rate was cut four more times reaching -0.5% and then returning to zero only July 2022.

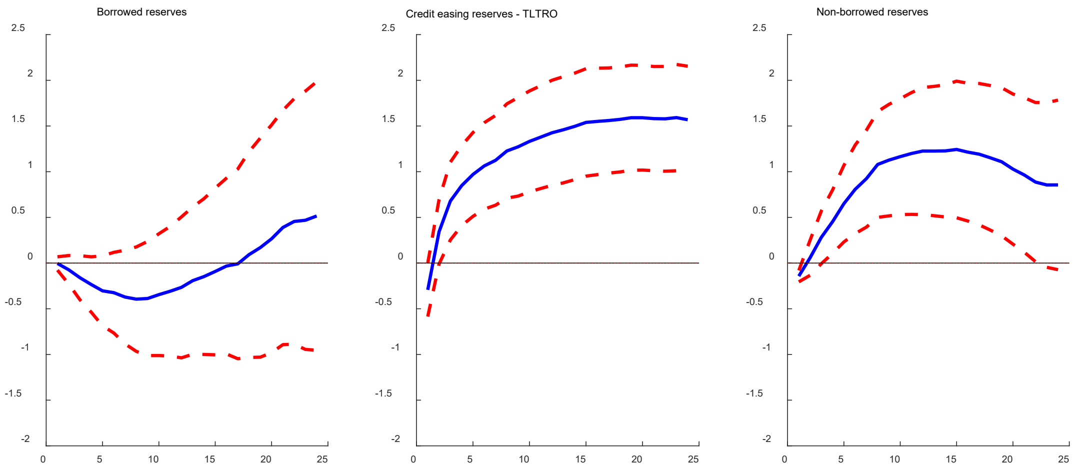
[30] The liquidity effect of asset purchases conducted under the securities markets programme (SMP) were sterilised until June 2014.

Figure 7 shows that, over this subsample, the effect of a change in borrowed reserves on lending activity was not statistically different from zero (panel A, Figure 7). The results do not change if the estimation sample starts in May 2014 and excludes the period prior to the launch of QE: a change in borrowed reserves has no impact on lending (panel B, Figure 7), while an increase in non-borrowed reserves is associated with a significant increase in loan supply (panel C, Figure 7).

The second exercise is meant to quantify the extent to which the empirical connection between non-borrowed reserves and loan origination might be due to the contemporaneous implementation of NIRP. Negative interest rates can affect bank lending and firm investment (see Rostagno *et al,* 2021; and Altavilla *et al*, 2022). The main mechanisms through which the exposure of individual banks to NIRP can affect lending travel via their share of deposits or their holdings of liquid assets. Previous studies found that banks with a large reserve base had a tendency to reduce their liquid asset holdings by more and to increase their lending to nonfinancial corporates more strongly (e.g. Bottero *et al* 2022). Other studies suggest that in a sample of syndicated lending, following the introduction of NIRP, the contraction in lending activity was larger for high-deposit banks than for low-deposit banks (e.g. Heider *et al* 2018).

To control for these potential cross-instrument interactions, we augment the benchmark model used above with two bank-specific variables: the share of non-financial private sectors deposits over assets and the share of liquid assets over total assets. Figure 8 reports the results of the local projections model augmented with the controls for NIRP. The picture is almost undistinguishable from that of Figure 6, indicating that the additional controls do not alter the quantification of the dynamic response of lending to a change in borrowed, credit easing and non-borrowed reserves. Once more, there is no statistical connection between loans and borrowed reserves. By contrast, the statistical connection between credit easing reserves and non-borrowed reserves is significant and large.

Figure 8: Response of bank loans after a rise in liquidity provision, controlling for NIRP



Note: The figure reports the cumulated response of banks' loan growth up to time *t+h* to an increase in TLTRO, non-borrowed and borrowed reserves ratio at time t. The solid line are retrieved from the coefficients β_h, δ_h, and λ_h from the regression $\Delta L_{i,t+h} = \alpha_{i,h} + \beta_h \Delta NBR_{i,t} + \delta_h \Delta BR_{i,t} + \lambda_h \Delta \mathrm{CER}_{i,t} + \Gamma_\mathrm{h} X_{i,t-1} + \epsilon_{i,t+h}$, $h = 1, \ldots, 24$. $\Delta L_{i,t+h}$ is the cumulated change in loans to firms of bank *i* between *t* and *t + h*; the variable $\Delta NBR_{i,t}$ and $\Delta BR_{i,t}$ represents the change in the ratio of borrowed and non-borrowed reserves over assets. $\Delta \mathrm{CER}_{i,t}$ is instead the ratio of credit easing reserves, i.e. TLTRO funds, over assets. $X_{i,t-1}$ includes the non-performing loan ratio, the return on assets, bank-specific credit demand conditions from the BLS, the share of government of government and corporate securities in the bank's assets, the level of excess liquidity over asses and the share of deposit of assets. In addition to the benchmark specification, we also control for the level of excess liquidity over asses and the share of deposit of assets. The dashed lines report the 95% confidence intervals for each horizon *h* with standard errors clustered at the country*time and bank level.

6. The real effects of different regimes of liquidity provision

The fourth testable hypothesis that we extract from our model analysis is that there is a robust effect of liquidity provision through CE and QE on the real economy. In this Section we want to test this model implication in the data. Specifically, we analyse if firms' economic activity – such as sales, investment and employment – is influenced by the source of reserves held by their counterpart banks. We investigate this question by matching bank-level information from AnaCredit, the euro area credit register, with firm-level data obtained from Bureau Van Dijk's Orbis – a comprehensive database of financial statements of companies worldwide. For each firm in Orbis, we calculate the weighted average of its counterpart banks' characteristics, most importantly the source of banks' reserve holdings : whether from regular refinancing operations, TLTROs or QE. We use the pre-existing credit exposures of each bank to each firm as the weights for this calculation.

The sample used in the empirical analysis consists of a cross-section of 120,973 firms operating in 86 Nace (Nomenclature of Economic Activities) sectors and distributed across 9 countries (Austria, Belgium, Germany, Spain, France, Greece, Italy, Portugal and Slovakia). The time frequency is annual, the estimation sample covers the period from 2018 to 2023, although to construct the variables used in the estimation we use data until 2008. Table 3 summarises the main variables that enter in or empirical analysis. Overall, our sample is highly representative of both aggregate and cross-sectional patterns in the euro area. This broad coverage enables us to analyse the real effects of central bank reserves effectively.

Table 3. Summary statistics for firm level data.

Variable Name	Units	Obs.	Mean	St. Dev.	Median
Sales	yoy	2,818,018	4.528058	54.76027	4.897205
Employment	yoy - No. employees	2,818,018	2.016814	37.03723	0
Investments	yoy	2,818,018	6.297684	65.28107	-2.19092
Firm Age	log - years	2,818,018	2.171098	.7489531	2.397895
Total Assets	log -EUR million	2,818,018	14.05745	1.693925	13.8559
Leverage	% of total assets	2,818,018	0.2435623	0.2313024	0.1946399
Non-borrowed reserves	% of main assets	2,818,018	3.662971	4.259802	2.298898
Borrowed reserves	% of main assets	2,818,018	0.0327158	0.2499879	0
Credit easing reserve	% of main assets	2,818,018	7.465933	6.539388	8.830747
Debtor probability of default (PD)	%	2,818,018	3.80	8.41	1.05%
Zombie	dummy	2,818,018	0.0129	0.1131	0

Notes: The unit of observation is the firm. All bank variables are averages across counterpart banks, with bank assets used as weights. To control for outliers, variables are winsorized at the top and bottom 1 percent of the sample. Investment is defined as tangible fixed assets. Debtor probability of default (PD) is the Moody's expected default frequency (EDF). Zombie is a dummy variable that takes value 1 if a firm has experienced an interest coverage ratio persistently below 1 over the three previous years and has been operating in the market for at least a decade.

We aggregate the dataset at the firm level and examine whether firms connected to banks with higher levels of credit easing and non-borrowed reserves tend to experience greater increases in investment, sales and employment compared to other firms. We saturate our models with firm, time, and industry-location-size (ILS) fixed effects. Our identifying assumption is that any shocks will affect firms within the same cluster in a similar manner. The specification used is the following:

$$\Delta Y_{f,t} = \alpha^{FE} + \Phi_{\mathrm{R}} \Delta R_{f,t-1} + \lambda PD_{f,t-1} + \Omega_{\mathrm{R}} \left(\Delta R_{f,t-1} \times PD_{f,t-1}\right) + \Gamma_h X_{f,t-1} + \epsilon_{i,f,t} \quad (10)$$

where ΔY represents, alternatively, the change in employment, sales, and investment of a firm f in year t. All explanatory variables are lagged by one year. $\Delta R_{f,t-1}$ represents the change in the reserve ratios measured with the three categories of reserves (borrowed, credit easing and non-borrowed reserves). Table 4 reports the results for all these firm outcome indicators. Two findings are noteworthy. First, the availability of borrowed reserves does not appear to impact firm outcomes, whereas an increase in credit easing and non-borrowed reserves is associated with higher growth in sales, investment, and employment. Firms connected to banks with higher levels of credit easing and non-borrowed reserves tend to receive more credit to fund higher levels of employment, and investment and support more sales compared to other firms.

Table 4: The real effects of central bank liquidity provision

	Sales			Employment			Investment		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\Delta BR_{f,t-1}$	3.450***	-0.122	-0.0825	0.597***	0.0233	0.0394	0.0277	-0.00437	-0.0249
	(0.198)	(0.194)	(0.195)	(0.140)	(0.141)	(0.141)	(0.287)	(0.290)	(0.291)
$\Delta CER_{f,t-1}$	0.0931***	0.0752***	0.0587**	0.105***	0.0407**	0.0458**	0.0580***	0.0832***	0.0834***
	(0.0117)	(0.0255)	(0.0256)	(0.00830)	(0.0177)	(0.0178)	(0.0140)	(0.0300)	(0.0301)
$\Delta NBR_{f,t-1}$	2.057***	0.438***	0.417***	0.586***	0.319***	0.315***	0.140***	0.354***	0.356***
	(0.0219)	(0.0261)	(0.0262)	(0.0148)	(0.0179)	(0.0180)	(0.0249)	(0.0307)	(0.0308)
$PD_{f,t-1}$	-0.0184	-0.0285**	-0.0446**	-0.0920***	-0.101***	-0.0986***	-0.272***	-0.267***	-0.266***
	(0.0217)	(0.0130)	(0.0213)	(0.0142)	(0.0142)	(0.0142)	(0.0217)	(0.0217)	(0.0217)
$PD_{f,t-1}$ x $\Delta BR_{f,t-1}$	0.0177	0.00323	0.00622	-0.0266	-0.0301	-0.0296	-0.0271	-0.0261	-0.0276
	(0.0318)	(0.0310)	(0.0311)	(0.0192)	(0.0192)	(0.0192)	(0.0300)	(0.0301)	(0.0301)
$PD_{f,t-1}$ x $\Delta CER_{f,t-1}$	0.00259*	0.00499***	0.00474***	0.0000556	0.000302	0.000282	0.0112***	0.0109***	0.0109***
	(0.00157)	(0.00154)	(0.00154)	(0.000967)	(0.000965)	(0.000966)	(0.00142)	(0.00142)	(0.00142)
$PD_{f,t-1}$ x $\Delta NBR_{f,t-1}$	0.0189***	0.0254***	0.0251***	0.00526***	0.00638***	0.00639***	0.00689***	0.00636***	0.00626***
	(0.00249)	(0.00242)	(0.00243)	(0.00152)	(0.00151)	(0.00152)	(0.00224)	(0.00225)	(0.00225)
Fixed Effects:									
Firm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time	-	Yes	Yes	-	Yes	Yes	-	Yes	Yes
ILS	-	-	Yes	-	-	Yes	-	-	Yes
Observations	2000021	2000021	1999864	2000021	2000021	1999864	1928872	1928872	1928715
R-squared	0.290	0.343	0.345	0.288	0.291	0.293	0.360	0.360	0.362

Note: The dependent variable is the annual growth rate of sales in columns 1 to 3, the annual growth rate of employment in columns 4 to 6, and the growth rate of investments in columns 7 to 9 for firms f at time t. $\Delta BR_{f,t-1}$ represents the change in borrowed reserves (MRO+LTRO) over main assets. $\Delta NBR_{f,t-1}$ denotes the change in non-borrowed reserves (excess liquidity-MRO-LTRO) over main assets. $\Delta CER_{f,t}$ is instead the ratio of credit easing reserves, i.e. TLTRO funds, over assets. PD is the firm-specific expected default frequency (EDF) constructed by Moody's as an indicator of borrower quality. The model includes other control variables, including firm age, leverage and size, as well as the set of fixed effects as reported in the table. ILS stands for industry-location-size fixed effects. Standard errors clustered at firm and time level. * p<.1, ** p<.05, *** p<.01.

Second, the statistical significance of the interaction term between PD, the probability of default, and non-borrowed reserves (NBR) is positive and significant. The same is true, for most of the specifications also for the credit easing reserves. This means that banks holding larger volumes of credit easing and non-borrowed reserves have a magnified incentive to lend. In corroborating a risk-taking channel of monetary policy, this finding is also consistent with one of our model results: CE and QE increase banks' risk tolerance even in the face of a probability of an adverse macroeconomic state that is invariant to monetary policy regimes.

This finding raises a further question. Isn't banks' increased tolerance for risk translating into excess risk-taking of the sort that is embedded in our model set-up? In other words, and in line with Stein (2012), wouldn't banks' propensity to build excessively risky exposures merit policies that *restrain* rather than encourage lending? We seek an answer to this question by investigating whether the availability of central bank funds might incentivize banks to direct credit towards unproductive firms that would typically exit the market, in what is known as "zombie lending" (see Caballero et al., 2008; Hoshi, 2006; Schivardi et al., 2022). The literature has used several methodologies for identifying zombie firms. For instance, firms may qualify as zombies if they fail to meet interest payments (e.g., Adalet McGowan et al., 2018; Acharya et al., 2019), are unable to secure credit at rates below market norms (Caballero et al., 2008), or exhibit persistently low or negative profitability (e.g., Schivardi et al., 2020). We define as "zombies" firms with an interest coverage ratio persistently below 1 over three consecutive years and operating in the market for at least a decade (Adalet McGowan et al., 2018). Importantly, this selection criteria should prevent misclassification of younger firms that are still developing their business, while at the same time still appropriately capturing distressed firms above and beyond measures based on interest payments.

Results in Table 5 indicate that firms borrowing from banks with higher volumes of non-borrowed reserves tend to exhibit better economic performance in terms of employment, sales, and investment. Although zombie firms generally perform worse economically, their exposure to banks with higher non-borrowed reserves does not influence this outcome. Firms borrowing from banks which drew reserves from TLTROs exhibit higher levels of employment and investment. Firms served by banks with reserves drawn from regular operations do worse in terms of all the three performance indicators. Overall, as in our model, an increase in bank credit supply as a result of CE or QE policies is not associated with excessive risk-taking or zombie lending.

Table 5: Impact on firm employment, investment, and sales

	Sales			Employment			Investment		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\Delta BR_{f,t-1}$	2.869***	-0.165	-0.0839	0.163	-0.273**	-0.243**	-0.395	-0.430*	-0.470
	(0.167)	(0.166)	(0.166)	(0.122)	(0.123)	(0.124)	(0.247)	(0.250)	(0.350)
$\Delta CER_{f,t-1}$	0.0159**	0.0192**	0.0197**	0.154***	0.0693***	0.0702***	0.0242**	0.153***	0.148***
	(0.00809)	(0.00974)	(0.01001)	(0.00708)	(0.0144)	(0.0145)	(0.0123)	(0.0250)	(0.0251)
$\Delta NBR_{f,t-1}$	1.774***	0.361***	0.365***	0.459***	0.214***	0.214***	0.126***	0.283***	0.275***
	(0.0179)	(0.0203)	(0.0203)	(0.0119)	(0.0139)	(0.0139)	(0.0209)	(0.0246)	(0.0247)
$Zombie_{f,t-1}$	-16.79***	-13.19***	-12.93***	-4.966***	-4.262***	-4.163***	-6.221***	-6.540***	-6.628***
	(1.640)	(1.576)	(1.580)	(0.960)	(0.958)	(0.959)	(1.444)	(1.445)	(1.448)
$Zombie_{f,t-1}$ x $\Delta BR_{f,t-1}$	0.277	0.457	0.540	-1.350	-1.319	-1.357	3.164	3.154	3.344
	(2.908)	(2.866)	(2.874)	(1.150)	(1.150)	(1.153)	(2.264)	(2.264)	(2.267)
$Zombie_{f,t-1}$ x $\Delta CER_{f,t-1}$	0.119	-0.0772	-0.0757	0.0723	0.0322	0.0316	0.253	0.280	0.283
	(0.108)	(0.105)	(0.106)	(0.0651)	(0.0650)	(0.0650)	(0.251)	(0.251)	(0.255)
$Zombie_{f,t-1}$ x $\Delta NBR_{f,t-1}$	-0.303	1.453	1.581	0.170**	0.103	0.110	0.0950	0.115	0.132
	(2.315)	(2.285)	(2.286)	(0.0860)	(0.0857)	(0.0864)	(0.130)	(0.130)	(0.129)
Fixed Effects:									
Firm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time	-	Yes	Yes	-	Yes	Yes	-	Yes	Yes
ILS	-	-	Yes	-	-	Yes	-	-	Yes
Observations	2427517	2427517	2427365	2427517	2427517	2427365	2261077	2261077	2260911
R-squared	0.283	0.331	0.335	0.288	0.292	0.294	0.360	0.360	0.362

Note: The dependent variable is the annual growth rate of employment in columns 1 to 3, the annual growth rate of investment in columns 4 to 6, and the annual growth rate of sales in columns 7 to 9, for firms f at time t. The variable ΔNBR and ΔBR represents the change in the ratio of borrowed and non-borrowed reserves over assets. The variable ΔCER is the change in the ratio of credit easing reserves (i.e. TLTRO) over assets. The variable Zombie is a dummy variable that takes value 1 if a firm has an interest coverage ratio persistently below 1 over three previous years and has been operating in the market for at least a decade. The model includes other control variables, including firm age, leverage and size, as well as the set of fixed effects as reported in the table. ILS stands for industry-location-size fixed effects. Standard errors are clustered at firm and time level. * p<.1, ** p<.05, *** p<.01.

Finally, we directly estimate the link between bank credit supply and firm outcomes.

Specifically, we first regress loans on borrowed, credit easing and non-borrowed reserves in the bank-firm panel to isolate the portion of lending driven by changes in each source of liquidity provision. We then incorporate the fitted values from this regression into the firm-level regressions to capture the impact of bank loans associated with each source of central bank reserves on firm outcomes.

Results reported in Table 6 indicate that firms with access to banks that boost their credit supply due to increased credit easing or non-borrowed reserves experience notable gains in sales, employment, and investments. In contrast, the performance of firms associated with banks that have higher borrowed reserves is not statistically different from other firms.

Table 6: Impact on the firm employment, investment, and sales

	Sales			Employment			Investment		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$E(\Delta BR_{f,t-1})$	8.541***	-0.303	-0.204	1.479***	0.0577	0.0974	0.0684	-0.0108	-0.0616
	(0.489)	(0.481)	(0.483)	(0.346)	(0.349)	(0.349)	(0.711)	(0.719)	(0.720)
$E(\Delta CER_{f,t-1})$	0.0931***	0.0752***	0.0587**	0.105***	0.0407**	0.0458**	0.0580***	0.0832***	0.0834***
	(0.0117)	(0.0255)	(0.0256)	(0.00830)	(0.0177)	(0.0178)	(0.0140)	(0.0300)	(0.0301)
$E(\Delta NBR_{f,t-1})$	3.547***	0.755***	0.719***	1.011***	0.551***	0.542***	0.242***	0.611***	0.613***
	(0.0378)	(0.0450)	(0.0452)	(0.0256)	(0.0309)	(0.0311)	(0.0428)	(0.0529)	(0.0532)
Fixed Effects:									
Firm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time	-	Yes	Yes	-	Yes	Yes	-	Yes	Yes
ILS	-	-	Yes	-	-	Yes	-	-	Yes
Observations	2000037	2000037	1999880	2000037	2000037	1999880	1928883	1928883	1928726
R-squared	0.290	0.339	0.343	0.291	0.294	0.297	0.360	0.360	0.362

Note: The dependent variable is the annual growth rate of employment in columns 1 to 3, the annual growth rate of investment in columns 4 to 6, and the annual growth rate of sales in columns 7 to 9, for firms f at time t. The variable $E(\Delta NBR)$ and $E(\Delta BR)$ represents the estimated change in bank lending due to the ratio of borrowed and non-borrowed reserves over assets. The variable $E(\Delta \text{CER})$ is the estimated change in bank lending due to the ratio of credit easing reserves over assets. The model includes other control variables, including firm age, leverage and size, as well as the set of fixed effects as reported in the table. ILS stands for industry-location-size fixed effects. Standard errors are clustered at firm and time level. * p<.1, ** p<.05, *** p<.01.

7 Conclusions

This paper studies an under-researched phenomenon: banks avoid borrowing from regular short-term liquidity-providing operations and, when they do so, they don't use the borrowed liquidity to back up their lending to the broader economy. We establish a non-equivalence result: banks are not indifferent to the origin of their liquidity endowments, whether obtained through short-term loans from the central bank, from credit easing interventions or outright transactions. We find a robust empirical connection between loans and reserves drawn from a credit easing program or non-borrowed, whereas no such connection exists between loans and borrowed reserves. It follows that a central bank which aims to expand lending and economic activity can do better than just offer banks an open-door access to such backup facilities on market conditions: it can lend liberally or sell a defined quantity of liquidity, both priced according to the Friedman rule. Credit easing and quantitative easing policies are instruments to implement the Friedman rule. They help align the private equilibrium to the central bank's lending and macroeconomic goals.

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Appendix 1. Model solution

Here, we provide detail on the solution and quantification of the three equilibria that we present in the main text. We start with the results concerning the LOLR equilibrium. For convenience we restate our first proposition:

LOLR

PROPOSITION 1: Denote as I^* the level of investment that banks choose when solving for the privately-optimum competitive allocation in a LOLR regime and as M^* the level of borrowing at the LOLR facility in case of a deposit run; denote also as I^{LOLR} the socially optimum level of investment chosen by the central bank in the same regime and as M^{LOLR} the quantity of borrowing under the LOLR facility consistent with I^{LOLR}. For $\alpha = 0$, and under plausible parameterisations of the model – including Stein's (2012) calibration – $I^{LOLR} > I^*$ and $M^{LOLR} > M^*$.

PROOF: To see this, imagine I^* equates the expressions on the two opposite sides of the equality sign in (2), and I^{LOLR} equates the two opposite sides of (5). Whether $I^{LOLR} > I^*$ depends on the relative size of the right-hand sides of (2) and (5), or, equivalently, on whether $\frac{x}{R^M}[R - R^{LOLR}] - \eta^{LOLR}\left[m\frac{g''(W-mIR^M)}{g'(W-mIR^M)^2}\right] < \left[\frac{1}{g'(W-mIR^M)R^M}[R - R^M] + \alpha\right]$. Note that the term on the right-side of this inequality is definitely larger than the first term of the left side, even with $\alpha = 0$, because $R^{LOLR} > R^M$ and $x = \frac{1}{g'(W-mIR^M)}$. Note also that the second term on the left side is positive, as $g''(W - mIR^M) < 0$. Adopting the parameterisation proposed by Stein (2012), the right-hand side term prevails even ruling out any positive externalities running across sectors, i.e. with $\alpha = 0$. The results for M^* and M^{LOLR} follow directly from the results for I^* and I^{LOLR}, recalling that $M^* = xI^*$ and $M^{LOLR} = xI^{LOLR}$.

COROLLARY 1: Imagine that, at the beginning of time-0 while the credit market session is still open, a macroeconomic shock intervenes to perturb a LOLR equilibrium in the making: the probability attached to the good state, p, falls to $p' < p$, detracting from the upside payoff from bank investments and simultaneously increasing the likelihood of a liquidity accident. Then, in the post-shock LOLR equilibrium: (1) banks will borrow more as a share of their assets than they would have in the absence of the shock, i.e. m^* is larger, but will invest less, i.e I^* is smaller; (2) the lending and monetary financing gaps, $I^{LOLR} - I^*$ and $M^{LOLR} - M^*$, both increase, i.e. banks' reluctance to intermediate becomes more acute.

PROOF: Taking a Taylor expansion of conditions (2) and (5) with respect to $dp = p' - p$, recalling the definition of R^{LOLR} and x in a LOLR environment, it isn't hard to see from (2) that, as $dp < 0$, the shock weakens the bank's expected upside to investing more and, at the same time, amplifies its expected loss should the bad state materialise. Note that the expected loss in LOLR is $\frac{1-x}{x} = g'(W - mIR^M\ ) - 1$, which is an increasing function in *I*. Lower investment and liquidity borrowing is therefore the privately-correct response to the shock. The impact on the policy calculus goes through the diminished upside to bank investment, but the central bank ignores the implication of the shock for banks' private loss. Accordingly, the impact of the shock on the social optimum is modest. At any rate, for both shocks, the distance between the socially optimal and the privately optimal levels of investment, i.e. the lending gap, increases.

COROLLARY 2: Imagine that, at the beginning of time-0 while the credit market session is still open, a macroeconomic shock drives α from 0 to $\alpha' > 0$. Then, while both I^{LOLR} and M^{LOLR} increase in response, I^* and M^* remain constant. In other words, banks' reluctance to intermediate increase if assessed against the norm set by the social optimum.

PROOF: Referring to (5), it's apparent that, assuming the right-hand side term between squared brackets prevailed numerically over the last term with $\alpha = 0$, it will do so *a fortiori* with $\alpha > 0$. As a result, denoting $I^{LOLR\prime}$ and $M^{LOLR\prime}$ as the values of investment and deposits that solve the social optimum problem after the shock, $I^{LOLR'} > I^{LOLR}$, and $M^{LOLR'} > M^{LOLR}$. As α doesn't enter (2), neither I^* nor M^* will change.

A NUMERICAL EXAMPLE. Here we adopt the same parameterisation as proposed in Stein (2012), and solve for the endogenous variables *I*, *M, m* and *W* that the private sector selects in a LOLR equilibrium. We also derive the social optimum for the same regime from the policy authority's welfare-optimising problem laid out in (4). The functional forms for the utility and the technologies and the numerical parameters are as follows: $f(I) = \psi \log(I) + I,\ g(K) = \theta \log(K) + \alpha I, R = 1.04, R^M = 1.01, \psi = 3.5, \theta = 150, p = 0.98,\ \ \tau = 0.5$. In searching for the private optimum and the central bank's welfare optimum, we have α vary between 0 – defining an economy without cross-sector production externalities as in Stein (2012) – and 0.005. We find that the private optimum solution in a LOLR regime comprises the following values for our endogenous variables: $I^* = 106.9$; $M^* = 60.0$; $m = 0.56$; $W = 144.2$. The same triplet solving the policy problem in the LOLR regime is the following: $I^{LOLR} = 112.3$; $M^{LOLR} = 62.5$; $m = 0.55$; $W = 146.0$, with $\alpha = 0$, and $I^{LOLR} = 128.8$; $M^{LOLR} = 67.5; m = 0.52$; $W = 146.2$, with $\alpha = 0.005$. Obviously, the gap between I^{LOLR} and I^* is increasing in α because I^* is insensitive to α. Under both parameterisations for α, the solutions imply a non-binding tax constraint. Following a negative shock to p, which brings the probability of a bad state from $p = 0.98$ to $p = 0.96$, the privately-optimal solutions for *I* and *M* plunge to $I^* = 88.7$ and $M^* = 53.6$, while the social optima for *I* and *M* remain roughly constant at

$I^{LOLR} = 110.5$ and $M^{LOLR} = 61.9$, respectively. Clearly, the lending and borrowing gap widen markedly if the probability of a liquidity crisis rises. At the same time, LOLR borrowing as a share of banks' assets increases from $m = 0.56$ to $m = 0.60$. It's also informative to compute the social optimum allocations in the non-interventionist (NI) social optimum analysed by Stein (with $\alpha = 0$): $I^{NI} = 99.6$; $M^{NI} = 58.7$; $m = 0.58$; $W = 147.0$, which compares with the privately-optimum allocations chosen by the economy in the same setting: $I \quad = 107.9$; $M \quad = 61.2$; $m = 0.56$; $W = 146.3$.

Credit Easing

Next, we report our second and third propositions concerning CE, applicable for $\alpha = 0$ and $\alpha > 0$, respectively.

PROPOSITION 2: Denote as I^{**} the level of investment that banks choose when solving for the privately-optimal competitive allocation in a CE regime and as M^{**} the corresponding level of borrowing in the CE facility; denote also as I^{CE} the socially optimal level of investment chosen by the central bank in the same regime and as M^{CE} the corresponding desired quantity of borrowings in the CE facility. For $\alpha = 0$, the private competitive allocations coincide with those prescribed by the societal optimum. In particular, $I^{CE} = I^{**} > I^{LOLR}$, and $M^{CE} = M^{**} > M^{LOLR}$.

PROOF: The result that the size of I^{CE} relative to I^{**} depends on α derives immediately from comparing the first-order condition for the socially optimal investment level using (6), after imposing the money-issuance constraint and $x = 1$, $pf'(I) + (1-p) - R = -\frac{1}{R^M}[R - R^{CE}] - \alpha$, and the first-order condition for investment from the bank optimisation problem, $pf'(I) + (1-p) - R = -\frac{1}{R^M}[R - R^{CE}]$, recalling that, in CE, $R^{CE} = R^M$. In the absence of production externalities, the two conditions are identical. The reason is that, by forgoing any loan over-collateralisation and setting $x = 1$, the central bank drives the private loss to the bank from borrowing under the CE facility, $\frac{1-x}{x}$, to zero. This term – present in the condition for the private optimum, but absent from the corresponding condition for a social optimum – typically introduces a wedge between the two conditions. The result concerning M^{**} and M^{LOLR} follow from the definition of *M*.

PROPOSITION 3: When $\alpha > 0$, $I^{CE} > I^{**} > I^{LOLR}$ and $M^{CE} > M^{**} > M^{LOLR}$.

PROOF: The level of investment that equates the two sides of the first-order condition for I^{CE} is obviously higher than the level of investment that equates the two sides of the first-order condition for I^{**}. The additional inequality result, $I^{CE} > I^{**} > I^{LOLR}$, descends from a comparison between the first-order conditions for a socially-optimal *I* in a CE regime and the first-order condition for a socially-optimal *I* under LOLR, (5), noting that, in the latter expression, $\frac{1}{g'(W - mIR^M)} = k < x = 1$, and the last term, $-\eta^{LOLR}\left[m\frac{g''(W-mIR^M)}{g'(W-mIR^M)^2}\right]>0$. The result concerning M^{**} and M^{CE} follow from the definition of *M*.

A NUMERICAL EXAMPLE. We adopt the same parameters as documented above and we solve for the endogenous variables *I*, *M*, m, *W* that the private agents and the central bank would choose under CE. The social optimum includes: $I^{CE}=M^{CE}=333.1$; $m=0.99$; $W=144.2$. Note that from the first order condition for *I* one can derive the policy-equilibrium level for investment as a closed-form function of the model parameters. The expression under our parameterisation is $I^{CE}=\frac{p\psi}{R-1-\frac{R-R^M}{R^M}-\alpha}=M^{CE}$. When $\alpha=0$, the CE policy optimum coincides with the CE private equilibrium. When $\alpha=0.005$, the policy optimum is: $I^{CE}=M^{CE}=647.5$; $m=0.99$; $W=144.2$, with the private allocations at: $I^{**}=M^{**}=333.1$; $m=0.99$; $W=144.2$, unsurprisingly mirroring the desired allocations in the social optimum with no externalities, as private agents ignore externalities anyway in formulating their decisions.

Quantitative Easing

PROPOSITION 4: Denote as I^{***} the privately-optimal level of investment selected by the banks in a QE regime, as P^{QE} the unit price at which the central bank is ready to purchase the banks' assets in a crisis, as $I^{QE}=I^{CE}$ and $M^{QE}=M^{CE}$ the central bank's targets for investment and deposits, respectively, under QE. For $\alpha>0$ not too far from zero and under plausible parameterisations of the model, $I^{***}=I^{QE}$ even with $P^{QE}=1$, which reproduces the valuation of asset collateral under CE.

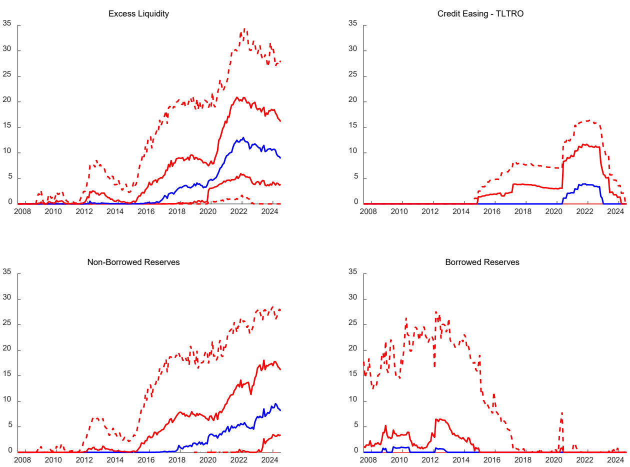
PROOF: The choice facing the banks is whether to create as much as $I^{QE}=I^{CE}$ in assets, with $I^{QE}=I^{CE}=\frac{p\psi}{R-1-\frac{R-R^M}{R^M}-\alpha}$, fund those assets by issuing $M^{QE}=M^{CE}$ in deposits, and sell M^{QE} to the central bank in a bad state, thus playing by the QE rules; or instead invest only I^* and issue M^* – the privately-optimal levels of investment and inside money in a LOLR regime, respectively – and access the LOLR facility posting $\frac{M^*}{x}$, with $x=\frac{1}{g'(W-M^*)}$, as collateral in a bad state. The final choice revolves around whether $\mathbb{P}^B_{QE}=pf(I^{QE})+(1-p)\,P^{QE}M^{QE}-RI^{QE}+I^{QE}(\frac{R-R^M}{R^M})\geq\mathbb{P}^B$, where $\mathbb{P}^B_{QE}$ denotes the banks' profits in the QE course of action, and $\mathbb{P}^B$, as detailed in (1), is the level of the banks' profits in the LOLR course of action. Note that the second term in the expression for $\mathbb{P}^B_{QE}$ can be explained by the fact that, in a bad state with the threat of a deposit run, the banks would sell an amount of assets equal to their deposit base M^{QE} in the QE option, thus forfeiting ownership of I^{QE}, the expected value of their assets in that state. However, recall from the discussion of the CE regime that $M^{QE}=M^{CE}=$

$mI^{CE}R^M = I^{CE} = I^{QE}$, as in CE $m = \frac{1}{R^M}$. Replacing M^{QE} with I^{QE} in the above inequality and collecting terms, we obtain the following expression: $p[f(I^{QE}) - f(I^*)] + (1-p)\,[P^{QE}I^{QE} - I^*] + \left(\frac{R-R^M}{R^M}\right)[I^{QE} - xI^*] \geq R[I^{QE} - I^*] - (1-p)(1-x)I^*$. As $I^{QE} > I^*$ and *f''(I) < 0,* there exist an $\alpha >$ 0 and an $x \leq 1$ big enough – which means an I^* small relative to I^{QE} – such that the terms on the right of the inequality prevail over the term on the left, i.e. $\mathbb{P}^B > \mathbb{P}^B_{QE}$. This is because a relatively large α increases the differential $R(I^{QE} - I^*)$, which in turn increases the cost to the banks of funding I^{QE} rather than I^* at the market interest rate *R.* In addition, if the non-bank technology is operated where the marginal product of the non-bank investment input is particularly low, *x* is pushed close to 1, and the scenario of having to access the LOLR facility in a bad state and over-collateralise a LOLR loan – which is the fallback option to selling into the QE program – is not too costly for the banks. In these conditions, banks would not participate in a QE program as sellers and would rather choose the LOLR option. However, for a sufficiently low, but positive, value of α, and a relatively large I^* – which compresses the value of *x* – the linear term in the investment differential, $R(I^{QE} - I^*)$ on the right of the inequality is dominated, so the inequality tends to be satisfied, even if the central bank purchases assets at a unit price $P^{QE} = 1$, which reproduces the valuation of the collateral under CE.

NUMERICAL EXAMPLE: As it turns out, by our parameterisation and assuming $\alpha = 0.005$, $\mathbb{P}^B_{QE} = 15.5$, and $\mathbb{P}^B = 12.6$, so the banks are better off funding as much as I^{QE} in physical investment and participating in the QE program if a liquidity crisis eventually erupts, than funding I^* and accessing the LOLR facility in the same strained conditions.

Appendix 2 – Bank level data used in the analysis

Figure A2.1: Liquidity measures across banks



Note: the chart shows for each month in the sample July 2007-July 2024 the median (solid blue line), the interquartile range (solid red lines) and the 10th-90th perc. (dashed red lines) of the individual bank distribution for the main variables employed in the empirical analysis.

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Carlo Altavilla
European Central Bank, Frankfurt am Main, Germany; Centre for Economic Policy Research, London, United Kingdom;
email: carlo.altavilla@ecb.europa.eu

Massimo Rostagno
European Central Bank, Frankfurt am Main, Germany; email: massimo.rostagno@ecb.europa.eu

Julian Schumacher
European Central Bank, Frankfurt am Main, Germany; email: julian.schumacher@ecb.europa.eu

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