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Why gradual and predictable? Bank lending during the sharpest quantitative tightening ever

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Challenges for Monetary Policy Transmission in a Changing World Network (ChaMP)

This paper contains research conducted within the network “Challenges for Monetary Policy Transmission in a Changing World Network” (ChaMP). It consists of economists from the European Central Bank (ECB) and the national central banks (NCBs) of the European System of Central Banks (ESCB).

ChaMP is coordinated by a team chaired by Philipp Hartmann (ECB), and consisting of Diana Bonfim (Banco de Portugal), Margherita Bottero (Banca d’Italia), Emmanuel Dhyne (Nationale Bank van België/Banque Nationale de Belgique) and Maria T. Valderrama (Oesterreichische Nationalbank), who are supported by Melina Papoutsi and Gonzalo Paz-Pardo (both ECB), 7 central bank advisers and 8 academic consultants.

ChaMP seeks to revisit our knowledge of monetary transmission channels in the euro area in the context of unprecedented shocks, multiple ongoing structural changes and the extension of the monetary policy toolkit over the last decade and a half as well as the recent steep inflation wave and its reversal. More information is provided on its website.

Abstract

Exploiting the recalibration of ECB's outstanding central bank funding in 2022, we show that a sharp reabsorption of bank liquidity induces a tightening impact on credit supply, as intended when central banks reduce their balance sheets. The tightening originates from the sudden relative convenience for banks accustomed to large liquidity holdings to more rapidly adapt to the new environment. Moreover, we show that the associated reduction in credit supply has real economic effects.

JEL codes: E51, E52, G21.

Key words: monetary policy, banking, credit supply, QT, liquidity.

Non-technical summary

The exceptional circumstances of the inflationary pressures in 2022 prompted the ECB to change the terms of its targeted longer-term refinancing operations (TLTRO III). This program had initially been designed to provide banks with cheap funding, encouraging them to lend more to businesses and households. The recalibration removed the impediments for an early voluntary repayment of borrowed funds, inducing banks to opt to repay a large portion of this funding much earlier than originally preferred and leading to a rapid contraction in aggregate liquidity.

Our study investigates the impact of this change, focusing on how it affected banks' willingness to lend and the subsequent effects on the real economy. We found that this sudden withdrawal of liquidity induced banks to quickly adapt to a new financial environment.

Banks with lower liquidity reserves faced increased funding costs as they looked for alternative sources of funding. This led them to reduce their lending, consistent with the well-known bank lending channel, where higher funding costs typically result in fewer credit being offered to borrowers.

Banks with higher liquidity reserves were also affected, although through different mechanisms. These banks often had significant off-balance sheet commitments backed by their liquidity, and the sudden convenience to repay outstanding central bank funding induced them to make quicker adjustments.

This resulted in a contraction of credit, affecting both existing loans and the issuance of new loans, consistent with the concomitant tightening of monetary policy. The impact was felt across the board, indicating that the pace of central bank balance sheet reductions can independently influence credit conditions, regardless of the starting liquidity levels of banks.

In addition, this reduction in credit had effects for firms, highlighting the direct link between the pace of central bank balance sheet reduction and real-world economic activity.

Our findings underscore the critical importance of the modality in which central banks implement changes to their balance sheets. The recalibration of TLTRO III in 2022 reached its stated goals to reinforce the transmission of our policy rates to bank lending conditions so that TLTRO III contributed to the transmission of the monetary policy stance needed to ensure the timely return of inflation to the ECB's 2% medium-term target. It contributed to normalise funding costs and removed deterrents to early voluntary repayments of outstanding TLTRO funds, with an associated large reduction of bank liquidity in a context of still ample reserves. In doing so, the recalibration of TLTRO III also taught us that faster adjustments in bank liquidity

can indeed reduce bank credit and reach the real economy, possibly offering a bank credit perspective to the arguments in favour of the gradual and predictable manner in which central banks, such as the European Central Bank (ECB), the Federal Reserve and the Bank of England, decided to reduce their balance sheets in normal times.

1 Introduction

When contracting their balance sheets, central banks in advanced economies tend to be very vocal about the gradual and predictable manner in which they plan to proceed. The FOMC stated this clearly in September 2014 in its 'Policy Normalization Principles and Plans'.[1] Bank of England followed in August 2021 (see Bank of England (2021)) and the European Central Bank in December 2022 (European Central Bank (2022), although ECB officials had stated the applicability of these principles to the euro area even earlier, see, e.g., Draghi (2018)).

Arguments in favour of these principles normally range between the potential signaling effects seen during the Taper Tantrum of 2013 (see, for example, Chari et al. (2020)) and concerns about market functioning (see, e.g., Logan and Bindseil (2019) and Copeland et al. (2024)). Comparatively, the role that these principles play in the bank-based transmission of monetary policy are considerably less explored. In this paper we exploit the recalibration of ECB's outstanding central bank funding in 2022 to illustrate how a rapid reabsorption of central bank reserves can induce a tightening of credit conditions, with rapid transmission to the real economy.

On 27 October 2022, the ECB announced that it was changing the conditions of outstanding TLTRO III funds as part of the monetary policy measures adopted to restore price stability over the medium term. This led a large part of the euro area banking system to front-load their plans to phase out of TLTRO III, prompting repayments of more than EUR 1 trillion of central bank funding by over 6 months earlier than previously expected. As a consequence, central bank reserves contracted at a pace and magnitude never experienced before in the Eurosystem. In parallel, bank credit slowed down, as intended by the tightening of monetary policy.

In this paper we use differential exposure to the recalibration of TLTRO III as a measure of the sudden withdrawal of liquidity. For identification, we use the sharp market reactions that followed the publication of a news report on 3 July 2022, which anticipated some features of the recalibration announced in October of the same year.[2] Bank bond yields showed abnormal increases in bank funding costs around this event, compared to historical regularities. The response of bank bond yields reflects the market's views of the challenges to banks' business stemming from either using banks' own liquidity or fetching the necessary

[1] See also the History of the FOMC's Policy Normalization Discussions and Communications.

[2] "ECB to discuss blocking banks from multibillion-euro windfall as rates rise," Financial Times, 3 July 2022.

liquidity via alternative funding sources to face the sudden repayments needs. Importantly, this impact came on top of the well-anticipated increase in funding costs associated with the then-ongoing phase-out of TLTRO III.

First, we show that the heterogeneous impact of the recalibration of TLTROs across banks, reflecting investors' views on the impact of the reabsorption of liquidity brought forward by the recalibration, decreased credit supply in the months following the shock.[3] To trace the impact of this shock to loan supply, we control for loan demand conditions via a Khwaja and Mian (2008) empirical set-up and include a large battery of variables capturing banks' exposure to concomitant monetary policy tightening cycle, fiscal policy measures against the energy crisis of 2022 and lingering impacts of the pandemic, among others. We document that the contraction in credit supply had an impact on existing borrowers in the intensive margin but also applied to the extensive margin, reducing the likelihood of new loans and increasing the likelihood of loan terminations. Moreover, at the firm level there also was a drop in credit for firms more exposed to the shock, pointing to the existence of aggregate effects of the policy.

Second, we show that the mechanism underlying this contraction was related to the pre-existing liquidity constraints and was mostly independent of banks' pre-existing liquidity levels due to the endogeneity of off-balance sheet exposures to the availability of liquidity. On the one hand, low-liquidity banks faced a larger need to gather expensive funding and therefore contracted credit because of the higher funding costs, consistent with the bank lending channel.[4] On the other hand, high-liquidity banks had larger off-balance sheet exposures backed by the very same liquidity to unwind, so they resorted to faster contraction in on-balance sheet exposures.[5] As a result, credit supply contracted for both types of banks, signaling that credit amplification stemming from the pace of balance sheet reduction acts independently from decisions on the magnitude of the reduction, or the starting point in terms of liquidity levels. Casting a link between the quantity of funding and cross-balance sheet interdependencies, the paper lends additional evidence to the relevance of a transmission of monetary policy through bank funding volumes.[6]

[3] The impact of central bank funding on bank funding costs and eventually lending conditions has been widely documented in the literature. See, e.g., Andrade et al. (2018), Altavilla et al. (2020b), Benetton and Fantino (2021), Carpinelli and Crosignani (2021), Altavilla et al. (2023a), Barbiero et al. (2024).

[4] Bernanke (1983); Bernanke and Blinder (1988); Kashyap et al. (1994); Bernanke and Blinder (1992); Kashyap et al. (1993); Kashyap and Stein (1994, 2000); Khwaja and Mian (2008); Jiménez et al. (2014a); Polo (2021).

[5] Kandrac and Schlusche (2021); Altavilla et al. (2022); Acharya et al. (2023); Acharya and Rajan (2024); Altavilla et al. (2023b); Fricke et al. (2024); Diamond et al. (2024).

[6] See, e.g., Drechsler et al. (2017), Stein (1998); Kashyap et al. (2002); Hanson et al. (2015); Drechsler et al. (2021) and Basten and Juelsrud (2023).

Third, we document that the contraction in credit supply stemming from the sudden need to repay central bank funding at the bank level had real effects. This evidence is consistent with a large body of literature showing that credit contractions do impact the real economy (Bernanke (1983); Cingano et al. (2016)). Moreover, while borrowers exposed to the shock were also more likely to fall into arrears possibly as a result of tighter credit conditions, banks did not rebalance their portfolios towards safer borrowers in response to the shock.[7]

The paper is organised as follows. Section 2 describes the circumstances in which the recalibration of TLTRO III occurred. Section 3 provides an overview of the unconditional adjustments in banks' balance sheets that occurred upon the reabsorption of excess liquidity associated with the front-loaded TLTRO repayments. Section 4 describes our data. Section 5 evaluates the impact of the shock on loan supply and explores the transmission mechanism. Section 6 presents evidence on the transmission to firm outcomes and potential real effects. Section 7 draws conclusions.

2 Institutional setting

Targeted longer-term refinancing operations (TLTROs) played a key role in preserving favourable bank financing conditions for households and firms in the euro area since 2014, as part of a broader set of complementary ECB policy instruments which included asset purchases, negative interest rates and forward guidance.[8] They consisted of repeated series of quarterly central bank funding operations, offered at attractive rates for longer horizons –from 2 to 4 years depending on the programme– than traditional refinancing operations. They were called "targeted" because, typically, the attractive borrowing conditions were subject to the achievement of lending targets. Since their inception in 2014, TLTROs have supported the transmission of monetary policy by incentivising lending through their targeting feature and by providing a reduction in bank funding cost.

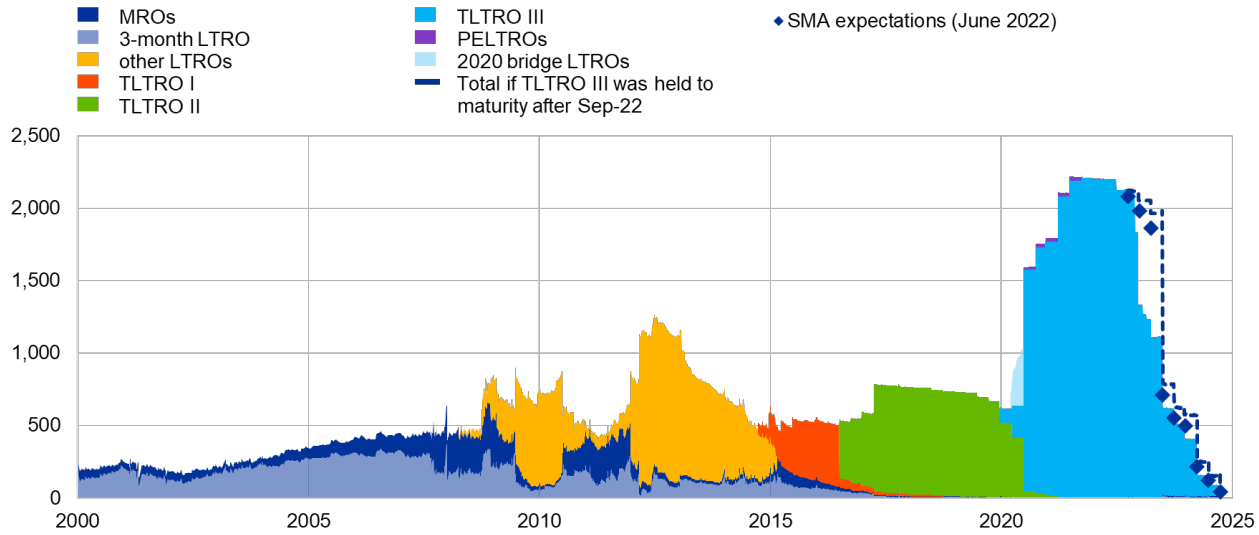
The third series of the TLTROs (TLTRO III) was introduced in early 2019 and was later recalibrated in 2020 in the context of the policy response to the pandemic crisis. Thanks to the very attractive conditions of the programme –with 3-year central bank funding offered at rates as low as -1%–, the liquidity strains

[7] This is referred at times as the risk-taking channel of monetary policy, see, e.g., Jiménez et al. (2014a), Gambacorta and Song (2018) and Altavilla et al. (2020a).

[8] See Rostagno et al. (2021).

brought about by the pandemic and the concurrent increase in the pool of eligible collateral, participation into the programme reached an all-time high of €2.2 trillion by June 2021 (see Figure 1).

Figure 1: **Central bank funding in the euro area**



Notes: the figure shows the (expected) amount of outstanding central bank funding by ECB refinancing operation in billion euros. Dots indicate the median expectations of monetary analysts in the Survey of Monetary Analysts in June 2022 for the outstanding amount of TLTRO-III over the following quarters. The blue line indicates the outstanding amount of TLTRO-III over the same quarters, had banks not used early repayment opportunities, thus holding borrowed amounts until maturity. Source: Barbiero et al. (2025).

Just as the participation into the programme helped to ease financing conditions for households and firms, the pre-scheduled phasing out of TLTRO III was likely to exert tightening pressure on bank lending conditions while potentially increasing incentives for risk taking, especially if accompanied by a diminished engagement of other monetary policy instruments and the broader policy environment. Due to the concentrated expiration of outstanding funds, as a result of front-loaded participation into the programme during the pandemic, congestion effects were expected to materialise in bank funding markets owing to the concurrent need to replace expiring TLTRO III funds with large volumes of bond issuance and other forms of more expensive funding, ultimately exerting gradual tightening pressure on bank lending conditions.

The radical change in inflation outlook materialised from mid-2021, at a pace and to an extent that was not anticipated by market participants, led to substantial repricing of interest rate expectations. The specific design of the TLTRO pricing, which was computing eventual interest rate expenses for borrowed funds over the life of the operations, implied that outstanding TLTRO funds were remunerated at a much lower

interest rate than most market-based alternatives with a comparable residual maturity. Moreover, the speed of adjustment of the interest rate on TLTRO III operations was slower also compared with changes in the deposit facility rate, that is, the rate at which the ECB was remunerating central bank reserves to steer the monetary stance into the tightening cycle. While marginal funding sources for banks like newly issued bank bonds were reflecting smoothly the ongoing repricing of interest rate expectations, the then-extant TLTRO pricing bore the potential of leaving this policy instrument misaligned with the broader monetary policy toolbox which was rapidly veering towards a tightening phase. For instance, market expectations over the timing of the voluntary early repayments of outstanding funds shifted outward in time, making the expected envelope of outstanding TLTROs in June 2022 mirror almost one-to-one the actual maturity of the funds (see Figure 1, blue diamonds and dashed line).

Thus, the ECB decided to recalibrate TLTRO III on 27 October 2022. The recalibration of TLTRO III increased the interest rate on the remaining operations from 23 November 2022 onwards leading to a sizeable correction of the borrowing costs under the programme. The change in TLTRO III conditions consisted of a change in the pricing formula of all outstanding operations (i.e. then 9 out of 10 operations).[9] Considering an evolution of policy rates in line with the prevailing market expectations back then, the change implied an effective increase in interest rate expenses for banks borrowing under TLTRO III of around 40 basis points, driven by the increase of around 2 percentage points in the TLTRO rate applicable after 23 November 2022. The heterogeneity between banks was large, with differences reflecting mostly the amount of outstanding TLTROs for each bank.[10] On average, these higher interest expenditures would have amounted to almost 10 basis points of return on assets (ROA) until the end of 2024 if banks had not repaid their funds early.

3 Bank balance sheets after the recalibration

After the change in TLTRO conditions, banks re-assessed the need to hold onto TLTRO funds.[11] The left-hand side panel of Figure 2 shows that, as a result of the recalibration, two large repayments took place

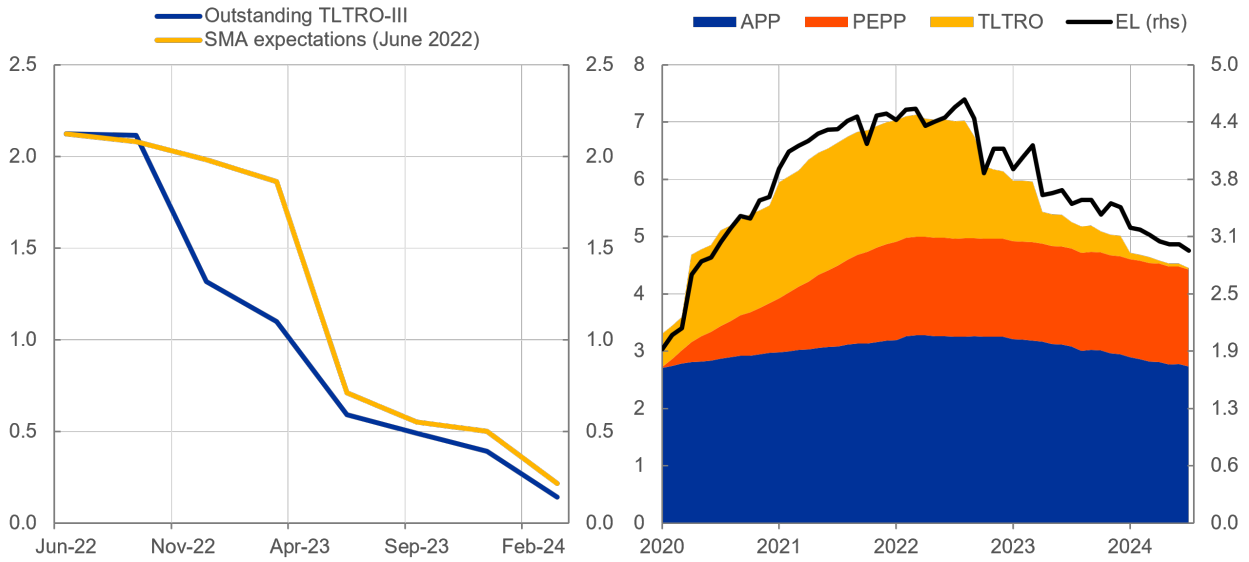
[9] The pricing formula after the recalibration was for the TLTRO rate over the lifetime of each operation to be the weighted average of the TLTRO rate before 23 November 2022 and the TLTRO rate after 23 November 2022, with weights equal to the periods before and after 23 November 2022. The TLTRO rate after 23 November 2022 was then indexed to the average key ECB interest rates after that date, reflecting the higher interest rate environment brought by the tightening cycle.

[10] There were also more minor differences depending on which operations each bank had participated in and the applicable interest rates based on past lending performance, although this applied to a very small percentage of banks.

[11] While banks had the ability to voluntarily repay TLTRO funds already, the recalibration also came with three additional voluntary early repayment opportunities, one in November 2022 and other two in January and February 2023.

in November and December 2022 for around €800 bn, against the €100 bn expected in June 2022 in the Survey of Monetary Analysts (SMA). This also led to a proportional fall in excess liquidity, as can be seen on the right-hand side panel of Figure 2. This was one of the largest and fastest re-absorption of excess liquidity in the history of the Eurosystem, equivalent to around 2% of banks' assets and 6% of euro area GDP, front-loaded by about half a year than previous expected by markets.

Figure 2: **TLTRO III, repayment expectations and central bank reserves in the euro area**



Notes: the left-hand side panel shows the actual amount of outstanding TLTRO-III funds, as well as median expectations of market analysts in June 2022 for the amount of outstanding TLTRO-III funds (i.e., before the leak about the recalibration), in trillions of euros. The right-hand side panel shows central bank assets by ECB programme (Asset Purchase Programme, Pandemic Emergency Purchase Programme and TLTRO, on the LHS scale) as well as excess liquidity in trillion of euros (on the RHS scale). Excess liquidity refers to the amount of central bank reserves held by commercial banks above minimum reserve requirements.

These early repayments occurred in a situation of still ample excess liquidity, made possible by sizeable central bank holdings of securities under the two main purchase programmes, i.e., the APP and the PEPP (in blue and red areas in Figure 2). This ample liquidity made the early repayments possible in the first place without creating massive disruptions in aggregate liquidity or impinging on aggregate regulatory liquidity ratios like the Liquidity Coverage Ratio (LCR) or the Net Stable Funding Ratio (NSFR), apart from localised shortfalls.[12] While the availability of unencumbered high quality liquid assets (HQLA) and the abundance of

[12]Considerations related to compliance with the NSFR were not particularly binding for early repayments of operations expiring by the first half of 2023 –the bulk of outstanding amounts–, due to their already low residual maturity.

liquidity, as well as other factors linked to balance sheet size (like bank levies or GSIB/OSI scores, especially ahead of year end), created some differences across banks in the incentives to repay early for banks, the main driver of the decision to repay early was the change in the interest rate expenses. TLTRO participants that could repay early did so by end-2022, those that could not faced the increase in average funding costs and reorganised their balance sheet policies accordingly.

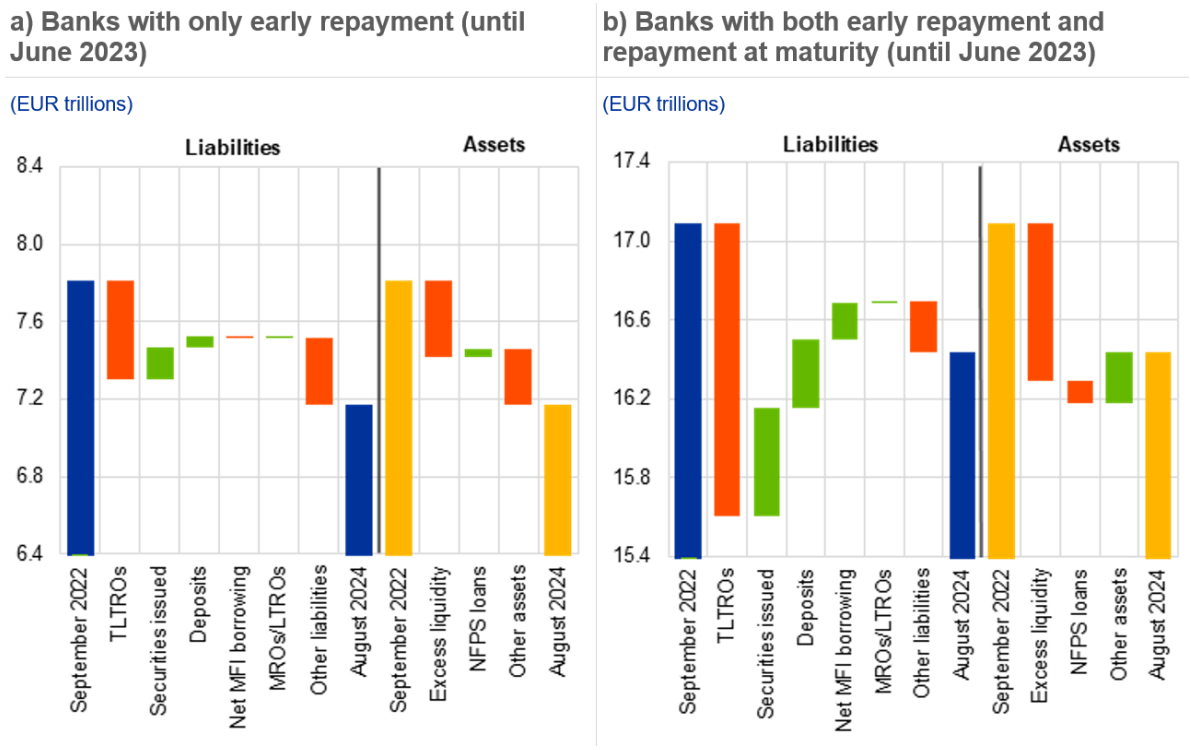
The two groups of banks differed mainly in their level of reliance on TLTRO III funding and in the size of their excess liquidity prior to the recalibration. Banks which only made use of early repayment options had on average almost twice as much excess liquidity as their outstanding TLTRO III borrowing prior to October 2022, while banks which also repaid at maturity had on average an amount of excess liquidity that was similar to their outstanding TLTRO III borrowing. Accordingly, the first group of banks reduced their excess liquidity by the equivalent of around 75% of their TLTRO repayments, thus relying primarily on existing excess liquidity, while also experiencing an outflow of deposits (Figure 3, panel a). By contrast, the second group of banks raised a significant amount of additional funding to repay TLTRO funds at maturity – predominantly via securities, followed by deposit inflows and borrowing on the interbank market – and only reduced their excess liquidity by the equivalent of around 50% of their TLTRO repayments (Figure 3, panel b). The second group also increased their deposit rates more than the other banks, thereby managing to preserve and, to a certain extent even increase, their overall deposit volumes to compensate for the ongoing decrease in liquidity.

The TLTRO repayments using outstanding excess liquidity reduced available liquidity positions, while the roll-over into other liabilities increased funding costs. This in turn seems to have led to tighter lending conditions to firms and households. The combination of these two reactions led to an acceleration in the reduction of the central bank balance sheet and ultimately an increase in the tightening impulse to bank credit. In the meanwhile, the euro area experienced, in the context of the monetary policy tightening, a very large slowdown in credit to firms (Lane (2024)).

4 Data sources

We rely on a wide range of data sources at the bank, firm and loan level. First, we obtain bank-level balance sheet data from the Individual Balance Sheet Items (IBSI) statistics. This monthly database is maintained

Figure 3: **Changes in bank balance sheets since the recalibration of TLTRO III**



Notes: the charts show how between September 2022 and August 2024 the assets and liabilities changed of banks that repaid TLTRO-III early (left-hand side) and banks that also repaid at maturity (right-hand side), indicating the contribution by balance sheet item. The blue and yellow bars indicate levels, red bars decreases and green bars increases. Source: Barbiero et al. (2025).

by the ECB and reports the main asset and liability items of the vast majority (more than 3000) of banks resident in the euro area. We make use of ECB Supervisory Reporting (FINREP) data to add additional bank characteristics, such as return on assets, CET1 ratio and non-performing loan ratio. Additionally, we use information on daily movements of bank bond yields from Markit iBoxx and intradaily movements in stock prices from Refinitv Eikon to identify higher-frequency changes in bank funding conditions and valuations. Second, the bank-level information is matched with firm-level data using the euro area credit register, AnaCredit, which contains all loans to euro area firms above €25,000. Third, the analysis of the real effects at the firm level makes use of firm characteristics derived from Bureau Van Dijk's Orbis Europe.

Our main sample consists of 69,553,726 observations from 2,693,544 bank-firm relations between 95 banks and 1,914,398 firms distributed across 14 countries, including Austria, Belgium, Cyprus, Germany, Estonia, Spain, Finland, France, Greece, Italy, the Netherlands, Portugal, Slovenia and Slovakia, over 48

Table 1: **Summary statistics**

Variable	Unit	Definition	Mean	St. dev.	Observations
TLTRO shock	%	Change in bond yields of bank b on 4 July 2022 interacted with a dummy equal to 1 from then on and 0 otherwise	0.041	0.063	69,553,726
Loan growth	%	Log-change in loan volume between firm f and bank b from month t to month $t+6$	-2.688	59.274	69,553,726
Assets	€mn	Main assets in month t of bank b	1236.297	116.713	69,553,726
Undrawn credit/Assets	%	Undrawn credit over assets in month t of bank b	1.560	1.441	69,553,726
Excess liquidity/Assets	%	Excess liquidity over assets in month t of bank b	12.174	5.800	69,553,726
TLTRO funds/Assets	%	TLTRO III volumes over assets in month t of bank b	10.448	5.267	69,553,726
Securities holdings/Assets	%	Securities holdings over assets in month t of bank b	8.852	6.221	69,553,726
Deposit ratio	%	Ratio of total deposits to total liabilities in month t of bank b	66.668	18.059	69,553,726
NPL ratio	%	Regulatory ratio of NPL over gross carrying amount of credit in month t of bank b	3.230	2.197	69,553,726
CET 1 ratio	%	Regulatory ratio of CET1 capital over risk-weighted assets in month t of bank b	14.097	3.295	69,553,726
Profitability	%	Return on assets in month t of bank b	0.410	0.418	69,553,726

Notes: Our main sample consists of 2,693,544 bank-firm relations between 95 banks and 1,914,398 firms over 48 months from January 2020 to December 2023.

months from January 2020 to December 2023. The summary statistics of our main sample are shown in Table 1.

5 The effects of the recalibration on loan supply

5.1 Main hypothesis and identification strategy

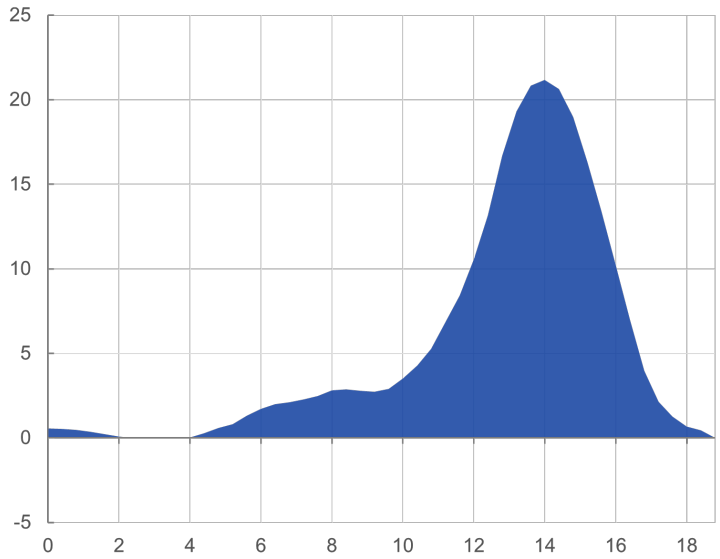
We test in what follows whether the front-loaded need to repay TLTRO funds and the associated sudden re-absorption of reserves in the second half of 2022 have contributed to the decrease in credit supply in the following months.

To achieve identification, we exploit the first news leak about a possible recalibration of the TLTRO III programme that was published in the Financial Times on Sunday, 3 July 2022.[13] This sourced story had not been anticipated by market participants, leading to a market reaction on 4 July 2022, the first business day after the article was published. We measure this market reaction with changes in individual banks' bond yields before and after the news release (henceforth, the 'TLTRO shock'). Figure 4 shows the increase in the yields of the bonds on 4 July.

The changes in bond yields on 4 July 2022 are tightly linked to the recalibration of TLTRO III and the

[13] "ECB to discuss blocking banks from multi billion-euro windfall as rates rise," Financial Times, 3 July 2022.

Figure 4: **Bank bond yields around news of the recalibration (the TLTRO shock)**

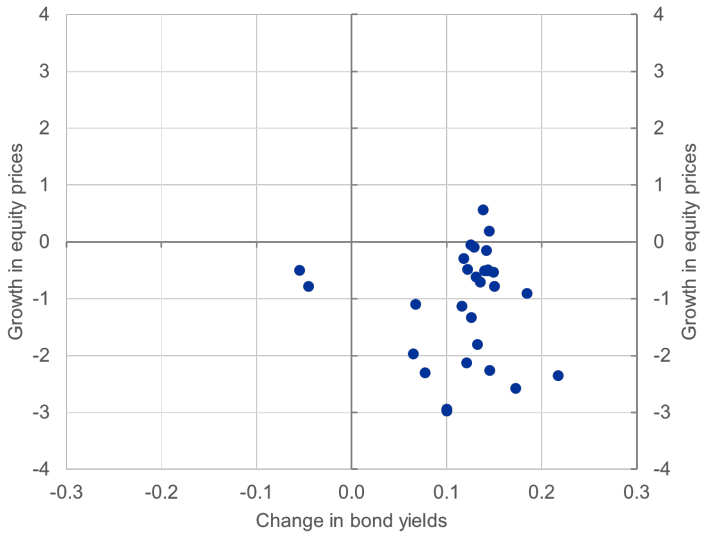


Notes: The charts shows the kernel density of bank-level changes in euro area bank bond yields (in basis points) from closure of business on Friday, 1 July 2022 to closure of business on Monday, 4 July 2022. The bank-level change in yields is used as TLTRO shock.

liquidity that was to be reabsorbed faster after the recalibration, which would ultimately occur later in the year. We reach this conclusion based on a series of tests. First, the yield increases in Monday, 4 July 2022 were abnormal even with respect to the historical regularities captured by a Fama-French 3-factor model. Estimating such a model for euro area daily changes in bank bond yields shows an average abnormal return highly correlated with the actual changes in bond yields. Second, Figure 5 shows that, even looking at intradaily changes in stock returns in the first business hours after the news had hit the markets, we observe sharp drops in bank stock prices immediately after market opening. Stock investors had the same reaction to the news at high frequency that bond investors had, with a generally negative revaluation of bank stocks immediately after markets opened on 4 July 2022 which matches the increase in bank bond yields. This evidence suggests that change in bond yields were indeed related to the news over the weekend instead of other announcements occurred over the remainder of the day.

Third, and most importantly, Table 2 shows that, of a wide series of bank characteristics, those that correlate the most with the change in bank bond yields on 4 July are closely associated with the outstanding excess liquidity allocated for the impending TLTRO repayments. The table divides the banks into two

Figure 5: **TLTRO shock and high-frequency change in bank stock prices**



Notes: The chart displays a scatterplot of TLTRO shock on 4 July 2022 (in percentage points and bank stock returns (in percent) in the first business hour after market opening on Monday, 4 July 2022, for the subset of banks which are publicly listed.

groups according to whether they experienced a relatively large or a relatively small TLTRO shock. Banks more exposed to the shock have significantly lower level of ex-ante outstanding excess liquidity, as well as lower quantity of alternative liquid assets that can still serve as HQLA in substitution of excess liquidity, like securities holdings. However, more and less exposed banks do not differ by the amount of TLTRO outstanding per se, suggesting that the impact of the phase-out of TLTRO per se was already fully priced in since it was well anticipated by market participants. Even the impact of recalibration per se on prospective interest rate expenses, which was directly proportional to outstanding amounts, was not the main driver of the increase in funding costs. Instead, the increase seems more closely related to the need to forego outstanding liquidity or to resort to alternative, more expensive sources of funding to fetch the necessary funds for an early repayment. Other bank characteristics normally relevant for bank intermediation also did not matter. For instance, the shock did not differ by bank size, the level of capitalisation and profitability, the riskiness of the loan portfolio, the reliance on deposits or bank bond funding. Interestingly, it did not differ even in terms of the distance to regulatory requirements related to liquidity such as the LCR, suggesting that the type of liquidity needs stemming from the front-loaded need to repay outstanding TLTROs were not mirrored into regulation, and arguably even supervisory scrutiny.

Table 2: **Bank characteristics by level of exposure to TLTRO shock**

	TLTRO shock above median		TLTRO shock below median		Difference between below and above median
	Mean	St.dev	Mean	St.dev	t-test
TLTRO shock	0.151	0.016	0.095	0.060	-6.151***
Excess liquidity/Assets	11.817	6.873	15.032	8.359	2.045**
Securities holdings/Assets	6.576	8.218	10.168	8.868	2.047**
HQLA/Assets	18.617	10.338	25.392	10.703	3.088***
(HQLA - TLTRO)/Assets	9.149	9.884	13.487	9.115	2.224**
TLTRO/Assets	9.244	6.785	11.714	8.639	1.548
Assets	131.745	214.405	159.656	238.955	0.599
CET 1 Ratio	16.678	4.590	17.620	10.743	0.554
Profitability	6.542	5.160	8.252	5.901	1.502
NPL ratio	2.170	3.118	2.849	3.429	1.009
Deposit ratio	64.728	21.632	66.650	24.356	0.406
Securities issued/Assets	17.303	15.609	18.117	21.210	0.213
Liquidity coverage ratio	223.953	89.486	254.049	145.597	1.095
Undrawn credit/Assets	0.800	0.934	1.082	0.982	1.271
Uninsured deposits/Liabilities	11.089	7.550	10.525	6.794	-0.383

Notes: The table presents means and standard deviations for selected bank characteristics within groups of banks by level of TLTRO shocks in July 2022. The table also reports t-tests of the differences in means between the two groups of banks. *** p<0.01, ** p<0.05, * p<0.1.

In order to trace the impact of the shock to bank lending conditions, we need to isolate the component of lending developments associated with shifts in the supply of credit from developments in loan demand. In order to control for loan demand, we make use of the information available at the bank-firm level from the credit register and include firm fixed effects as in Khwaja and Mian (2008) to control for firm-specific unobservable heterogeneity in loan demand. The variation stemming from exposure to the shock at the bank level within each firm allows us to achieve identification of loan supply shifters.[14] Since we want to look at the reaction of lending to the shock in July 2022, we focus on changes in loan volume after the shock. Given the availability of panel data for the lending conditions at the bank-firm level, we adopt a local projection set-up à la Jordà (2005). Our benchmark model is then as follows:

$$\text{Loan growth}_{b,f,t+h} = \beta^h \text{TLTRO shock}_{b,t} + \delta^h X_{b,t} + \alpha^h_{f,t} + \alpha^h_{b,f} + \varepsilon^h_{b,f,t}, \quad (1)$$

where $\text{Loan growth}_{b,f,t+h}$ is the percentage change of loan volume (measured as changes in log-volumes) between bank b and firm f in the months from month t to month $t+h$. $\text{TLTRO shock}_{b,t}$ is our treatment variable, which is the interaction between the time-invariant exposure to the shock in July 2022, TLTRO shock_b,

[14] See also Amiti and Weinstein (2018) and Jiménez et al. (2014b).

and a dummy Post_t that takes value 1 in months after July 2022 and 0 before. $X_{b,t}$ are time-varying bank characteristics that capture confounding factors. In particular, it includes factors normally associated with banks' willingness to lend like bank size, capitalisation (CET 1 ratio), profitability (ROA), exposure to credit risk (NPL ratio) but also their liability structure (deposit ratio). Moreover, it includes variables more directly related to exposure to the TLTRO phase out and the recalibration itself (TLTRO outstanding) as well as bank characteristics that we know being associated to our shock (excess liquidity and securities holdings) so as to make sure that even unobserved factors that may have determined a given level of excess liquidity or securities holdings and that also affect loan supply drive our results. $\alpha_{f,t}$ are firm-month fixed effects that mop up loan demand developments, and $\alpha^h_{b,f}$ are bank-firm fixed effects that capture time-invariant characteristics associated with the specific lending relationship between bank b and firm f.

Our key coefficient β^h then measures the different loan growth over h months between bank b and firm f associated, after July 2022, with one percentage point difference in exposure to the TLTRO shock in July 2022, and that is not explained by a common increase in lending to the same firm by other banks independently of their exposure to the shock. Since our main regressor varies at the bank level and across two periods, we control for the spurious correlation in errors $\varepsilon^h_{b,f,t}$ introduced in this way by clustering standard errors at the bank and post-shock level. As a benchmark, we look at changes in lending volumes six months ahead but we offer a battery of robustness checks and placebo exercises to corroborate the evidence that the observed response in lending volumes is indeed associated with the TLTRO shock and originating from a transmission mechanism that crucially revolves around the liquidity needs of banks.

While the unexpected nature of the shock and our empirical strategy allows for a causal interpretation of the estimated coefficients, we provide in what follows an extensive battery of robustness tests and dedicated exercise to examine the role of potentially confounding factors. First, the ECB started to hike rates in July 2022 but had entered a phase of monetary policy normalisation as early as December 2021. Second, the Russian invasion of Ukraine had created uncertainty around euro area banks' exposures to the countries involved as well as through potential ripple effects emerging from the energy crisis that ensued, as well as the fiscal response to that crisis in the form of energy subsidies. Third, it is possible that the actual increase in interest rate expenses associated with the eventual announcement of the recalibration of TLTRO III on 27 October 2022 may infuence spuriously our estimates. To incorporate all these circumstances in our analysis, we run dedicated horse races where the concurrent shocks do not affect the key estimates, confirming that

our exercise isolates the impact of the front-loaded, unexpected absorption of excess liquidity.

5.2 Main results

Table 3 reports the main estimation results, showing that the impact of the shock on loan growth grew over time and was not preceded by a pre-existing trend in lending growth spuriously correlated with the exposure to the shock. The estimated coefficient points to a sizable impact of the TLTRO shock on loan growth in the months after July 2022, with a drop in loan growth of between 0.9 and 1.5 percentage points for each standard deviation of higher bank bond yields registered upon learning of the recalibration of TLTRO and the likely need to repay TLTRO funds earlier than originally planned. The impact is economically significant, as one standard deviation of the shock is associated with 3% of a standard deviation of loan growth 6 months ahead and more than half of its mean. The 0.9 percentage points of lower annual loan growth predicted by our most conservative coefficient in Column (4) compares with a total drop in annual growth of around 7 percentage points from end-2022 to end-2023.[15]

Table 3: **Impact of TLTRO shock on lending**

Dependent variable:	(1) Loan growth 12 months before	(2) Loan growth 6 months before	(3) Loan growth 6 months ahead	(4) Loan growth 12 months ahead	(5) Loan growth 18 months ahead
TLTRO shock	-3.796	0.189	-18.203*	-14.019***	-24.347***
	(4.687)	(4.138)	(10.675)	(4.815)	(6.510)
Bank controls	Yes	Yes	Yes	Yes	Yes
Bank-firm FE	Yes	Yes	Yes	Yes	Yes
Firm-time FE	Yes	Yes	Yes	Yes	Yes
Observations	41,001,833	53,827,053	69,553,726	53,732,925	40,845,953
R-squared	0.657	0.534	0.533	0.653	0.704

Notes: The table presents the estimates for β^h for model (1), which is the coefficient in the regression at the bank-firm-time level loan growth from month t to month $t+h$ on the TLTRO shock. Each column represents a separate regression on a different horizon h, for $h = -12, -6, 6, 12, 18$. Bank controls include bank assets, excess liquidity over assets, TLTRO funds over assets, securities holdings over assets, deposits over liabilities, the NPL ratio, the CET1 ratio and return on assets. Standard errors are clustered at the bank and post-shock level. See Table A.1 for the coefficients on the control variables. * p<0.10, ** p<0.05, *** p<0.010.

Table 4 reports several tests for the relevance of this channel. By construction, the benchmark model (1) focuses on the intensive margin of lending, that is, on the increase in outstanding amounts for bank-firm relations that already exist and keep existing over the specific horizon. Yet, there may be a substantial margin

[15] Table A.1 reports all the coefficients associated with the control variables. Table A.2 shows the estimates of an alternative model where TLTRO $\text{shock}_{b,t}$ is defined as the interaction between the same TLTRO shock_b and an alternative dummy Post_t that takes value 1 in July 2022 only and 0 in the months before and after. The statistical significance and magnitude of the coefficients is similar.

of adjustment also in new relationships being created or not in the meanwhile, as well as additional lending relationships reaching termination. Column (1) shows the same specification with a different definition of the dependent variable in terms of inverse hyperbolic sine function, which allows for relations that were ex ante or ex post nil to be included in the regression. The estimated coefficient remains statistically significant and sizable. Since the extensive margin of credit seems to be relevant from a statistical point of view, we test for it explicitly in Columns (2) and (3). Column (2) shows one standard deviation of the TLTRO shock predicts a decrease of the probability of a new lending relationship in our sample of around 10% of the unconditional average entry rate (0.6%). Column (3) shows that the same shock also predicts a similar increase in the probability that an existing relationship is terminated, accounting for 2% of the unconditional average exit rate in our sample (1.9%).

Table 4: **Margins of adjustment in lending and firm-level evidence**

Dependent variable:	(1) Loan growth 6 months ahead ΔIHSF	(2) Probability of a new relation 0/1	(3) Probability of a terminated relation 0/1	(4) Firm loan growth 6 months ahead ΔLog	(5) Firm loan growth 6 months ahead ΔLog
TLTRO shock	-6.640***	-0.010***	0.006**	-3.308***	-14.385***
	(1.420)	(0.002)	(0.002)	(0.767)	(0.449)
Firm loan demand					0.924***
					(0.001)
Bank controls	Yes	Yes	Yes	No	No
Firm-level bank controls	No	No	No	Yes	Yes
Bank-firm FE	Yes	Yes	Yes	No	No
Firm-time FE	Yes	Yes	Yes	No	No
Firm FE	No	No	No	Yes	Yes
Country-time FE	No	No	No	Yes	Yes
Observations	96,113,198	106,011,452	106,011,452	40,357,438	40,357,438
R-squared	0.444	0.257	0.262	0.092	0.421

Notes: The table presents the estimates for β^h for models identical to model (1), with a different dependent variable as indicated (all columns) or bank controls aggregated to the firm level (Columns (4) and (5)). Column (1) takes as dependent variable 6-month loan growth in terms of inverse hyperbolic sine function, Column (2) has as dependent variable whether the bank-firm relationship is new (taking the value 1) or existing (0), Column (3) takes as dependent variable whether the bank-firm relationship is terminated in that period (taking the value 1) or continues to exist (0). Columns (4) and (5) are regressions at the firm-level, for which bank-firm level data are aggregated to the firm-level; bank-firm FE are replaced by firm fixed effects and firm-time FE are replaced by country-time FE. Column (5), moreover, includes the firm FE estimate from the specification in Column (3) of Table 3, to capture firm loan demand. Standard errors are clustered at the bank and post-shock level for Columns (1) to (3) and at the firm level for Columns (4) and (5). * p<0.10, ** p<0.05, *** p<0.010.

In Column (4) of Table 4 we aggregate credit at the firm level and take the averages of TLTRO shock and bank controls at the firm level (weighted by pre-existing exposures at the bank-firm level). The exercise shows that even if firms may have substituted some of the foregone credit between banks more exposed with

credit from banks less exposed, there was also an outright decrease in credit at the firm level. Column (5) goes a step further considering that at the firm level we cannot fully control for a time-varying loan demand in the same way as in our bank-firm setting of model (1). If the demand at the firm level were to be correlated with actual loan growth at the firm level, its omission would lead to biased results. Thus, we follow Cingano et al. (2016) and include the firm fixed effects estimated in Column (3) of Table 3 as a control in a firm-level regression. In this way, we mop up the variation in loan growth at the firm level that is not explained by the variation of our exposure variable across banks, leading to consistent estimates of the impact of the TLTRO shock on firm borrowing. By controlling for firm demand, the resulting coefficient is similar to the bank-level evidence and shows that, independent of the spillovers across banks, exposure to the TLTRO shock led to a sizable drop in loan supply received by firms.

Table 5 shows that exposure to other shocks did not confound the transmission of the TLTRO shock to lending conditions. We consider three concurrent shocks: the switch of monetary policy stance, the Russian invasion of Ukraine and subsequent energy shock, and the actual announcement of the recalibration of the TLTRO III programme.

Table 5: **Exposure to concurrent shocks**

Dependent variable:	(1) Loan growth 6 months ahead	(2) Loan growth 6 months ahead	(3) Loan growth 6 months ahead
TLTRO shock	-20.353*	-22.300*	-24.790**
	(11.500)	(11.947)	(12.423)
Bank controls	Yes	Yes	Yes
Bank-firm FE	Yes	Yes	Yes
Firm-time FE	Yes	Yes	Yes
Bank-Post(Dec 2021) FE	Yes	No	No
Bank-Post(Feb 2022) FE	No	Yes	No
Bank-Post(Oct 2022) FE	No	No	Yes
Observations	69,553,726	69,553,726	69,553,726
R-squared	0.533	0.533	0.533

Notes: The table presents the estimates for β^h with $h = 6$ for models similar to model (1), again capturing the coefficient on the regression of loan growth from month t to month $t+h$ on the TLTRO shock. The difference relative to (1) and the results in Table 3 are the inclusion of additional fixed effects as indicated in the table. The estimated equation is thus $\text{Loan growth}_{b,f,t+6} = \beta^6 \text{TLTRO shock}_{b,t} + \delta^6 X_{b,t} + \alpha^6_{f,t} + \alpha^6_{b,f} + \alpha^6_b \times \text{Post(Date)}_t + \varepsilon^6_{b,f,t}$, where $\alpha_b \times \text{Post(Date)}_t$ is the interaction between a bank dummy and a dummy identifying the periods before and after the Date, with Date being December 2021 (Column (1)), February 2022 (Column 2) and October 2022 (Column (3)). Standard errors are clustered at the bank and post-shock level. * p<0.10, ** p<0.05, *** p<0.010.

Column (1) shows the tightening cycle, whose start can be assigned to the first announcement by the

ECB in December 2021 of the incoming stop to active asset purchases under the PEPP, and its impact on credit conditions were fully operational in parallel to the TLTRO shock, without any of the two impinging on the transmission of the other. Column (2) shows that the energy shock that followed the Russian invasion of Ukraine, including the fiscal response to it, did not blur the increase in funding costs associated with the TLTRO recalibration, even when considering its reflection on banks' balance sheets. Column (3) shows that the actual recalibration announcement did not have effects on funding conditions and eventually lending, since by then most of the content of the recalibration was already priced in.

5.3 Additional evidence on the mechanism

The bank characteristics associated with the TLTRO shock in Table 2 and our benchmark specification already pinpoint the mechanism of transmission of the recalibration shock to the sudden need to repay outstanding TLTROs. In this section, we provide further evidence that the mechanism underlying this contraction relies on the extent to which banks were facing liquidity constraints before the shock. Facing the sudden need to rethink their asset and liability management and their funding plans for the remainder of the year, banks actively cut credit supply to avoid the materialisation of liquidity strains after the recalibration and the more swift shift to a situation of overall lower liquidity. Importantly, we also show that the reaction of credit supply did not mechanically depend on the size of the forthcoming repayments or the quantity of ex-ante liquidity per se, as these were arguably associated with different bank balance sheet structures and business models. For instance, the maturity of on-balance sheet exposure, the size of off-balance sheet exposures and the abundance of uninsured deposits are endogenous to the liquidity environment (Acharya et al. (2023)). Thus, the proportion to which banks cut lending depended on how sizable their liquidity constraints were ex ante.

In Table 6 we test whether the reaction to the TLTRO shock differed depending on bank characteristics crucially associated with potential mechanisms of transmission, above and beyond what could have already been captured by our extensive battery of controls. In Column (1) we show that the contraction was not proportional to the size of TLTRO outstanding, which was also directly connect to the change in interest rate expenses associated with the recalibration per se. The coefficient, though differing in statistical significance, did not differ in terms of magnitude between banks with low TLTRO outstanding and other banks. If anything, the coefficient was slightly higher for banks with lower TLTRO funds, potentially reflecting a

composition effect whereby banks with lower TLTRO funds in June 2022 were also those marginally more reliant on bond issuance and hence more directly exposed to the change in funding costs early on. Column (2) shows that also the availability of excess liquidity was not a key determinant of the response of credit supply to the TLTRO shock. This is likely the result of the endogeneity of banks' balance sheet structure and business model to liquidity levels. One the one hand, low-liquidity banks faced a larger need to gather expensive funding and therefore contracted credit because of the higher funding costs, consistent with the bank lending channel. On the other hand, high-liquidity banks had larger off-balance sheet exposures backed by the very same liquidity to unwind, so they resorted to faster, more abrupt contraction in on-balance sheet exposures. As a result, credit supply contracted for both types of banks, signaling that credit amplification stemming from the pace of balance sheet reduction acts independently from decisions on the magnitude of the reduction, or the starting point.

Table 6: **Impact of TLTRO shock by banks' exposure to liquidity frictions**

Dependent variable:	(1) Loan growth 6 months ahead	(2) Loan growth 6 months ahead	(3) Loan growth 6 months ahead	(4) Loan growth 6 months ahead
Exposure by:	TLTRO funds	Excess liquidity	Undrawn credit	Uninsured deposits
TLTRO shock with low exposure	-21.686***	-6.835**	-3.973	4.410
	(6.085)	(2.675)	(3.208)	(13.925)
TLTRO shock with high exposure	-17.447	-23.390	-20.011*	-20.890*
	(13.598)	(14.350)	(11.424)	(11.424)
Bank controls	Yes	Yes	Yes	Yes
Bank-firm FE	Yes	Yes	Yes	Yes
Firm-time FE	Yes	Yes	Yes	Yes

Notes: Each coefficient within a column represents the result of a separate regression estimating β^h for model (1) with $h = 6$ within a sample defined by the exposure variable reported in each column. Exposure variables are measured in June 2022. The low exposure sample consists of the loans of banks belonging to the bottom tercile of the distribution of the exposure variable. The high exposure sample are the loans of all other banks. All exposure variables are defined in percentage of main assets, uninsured deposits are defined as the sum of deposits from non-financial corporations and deposits from insurance corporations and pension funds. Standard errors are clustered at the bank and post-shock level. * p<0.10, ** p<0.05, *** p<0.010.

In Columns (3) and (4) of Table 6 we take explicitly into consideration the so-called liquidity dependence generated by pre-existing liquidity, that is, some features of banks' balance sheet structure that depend on the availability of central bank reserves. Acharya et al. (2023) has shown how higher liquidity is associated with higher off-balance sheet exposure and higher availability of uninsured, usually more flighty deposits by non-financial corporations and non-bank financial intermediaries. If liquidity is withdrawn at a fast pace, the combination of rapidly decreasing uninsured deposits and credit line committed before the shock can be a

source of liquidity distress for intermediaries. In the case of our TLTRO shock, which de facto constitutes a sudden, unforeseen and sizable drop in available liquidity several months before originally scheduled, we can see that banks react to such liquidity risks swiftly and decisively. Column (3) shows that the impact on credit supply is driven by banks that before the shock had larger off-balance sheet exposures in the form of already granted but not yet drawn credit. Similarly, Column (4) shows that roughly the same applies to the case of reliance on uninsured deposits as a source of financing. Banks with more flighty deposits were also the ones reacting the most to the incipient liquidity drainage.

Table 7 presents further evidence that the main concern for banks in response to the news of the incoming recalibration was to reduce liquidity risk. The more-than-proportional contraction of on-balance sheet exposures in response to off-balance sheet exposures is consistent with a precautionary behavior of banks towards their exposure to liquidity risks associated with the front-loaded repayment of TLTROs. Thus, banks more exposed to the TLTRO shock are likely to have reduced the residual maturity of their loan book, as banks in early July 2022 received a signal that the liquidity environment that underpinned longer-term credit exposures was bound to quickly disappear. Column (1) shows that exposed banks reduced the maturity of their loan portfolios. Each standard deviation of TLTRO shock was associated with a 0.6% reduction of average residual maturity of outstanding credit, equivalent to around 9 days. At the same time, this qualitative recomposition of the loan portfolio was directed toward reducing liquidity risk alone, without necessarily affecting credit risk exposures.

Columns (2) and (3) of Table 7 show that, while banks may have indeed reduced their credit risk-taking in the overall tightening context, they did not do so depending on their exposure to the liquidity needs brought about by the TLTRO recalibration. Banks did not rebalance their credit supply away from ex-ante riskier borrowers relative to ex-ante safer borrowers, both in the intensive margin of Column (2) and in the extensive margin of Column (3). This apparent lack of shifts in risk attitudes towards credit risk also suggests that banks did not internalise the potential correlation between the decrease in aggregate credit supply associated with the recalibration of TLTROs and the acceleration in credit quality deterioration that this may have entailed.

Table 7: **Impact of TLTRO shock on bank risk taking**

Dependent variable:	(1) Growth in residual maturity 6 months ahead ΔLog	(2) Loan growth 6 months ahead ΔLog	(3) Loan growth 6 months ahead ΔIHSF
TLTRO shock	-9.302**	-23.980*	-7.113***
	(3.673)	(12.261)	(1.669)
TLTRO shock × Borrower's ex-ante PD		0.155	0.021
		(0.098)	(0.114)
Bank controls	Yes	Yes	Yes
Bank-firm FE	Yes	Yes	Yes
Firm-time FE	Yes	Yes	Yes
Observations	46,434,858	54,759,168	70,760,060
R-squared	0.567	0.500	0.444

Notes: The table shows regressions similar to model (1), with a different dependent variable (Columns (1) and (3)) and an additional regressor (Columns (2) and (3)). The dependent variable in column (1) is the percentage change in residual maturity of outstanding credit from month t to month $t+6$. The dependent variable in Column (3) is 6-month loan growth defined in terms of an inverse hyperbolic sine function, as also seen in Column (2) of table 4. Columns (2) and (3) include an additional regressor that is an interaction of the TLTRO shock and borrower's ex-ante probability of default (PD). The estimated equation is thus Loan growth$_{b,f,t+6} = \beta^6$TLTRO shock$_{b,t} + \zeta^6$TLTRO shock$_{b,t} \times$ Borrower's ex-ante PD$_b + \delta^6 X_{b,t} + \alpha^6_{f,t} + \alpha^6_{b,f} + \varepsilon^6_{b,f,t}$, where Borrower's ex-ante PD$_b$ is the average probability of default of firm f reported for regulatory purposes in banks' balance sheets by all banks servicing that borrower, measured as of June 2022. Standard errors are clustered at the bank and post-shock level. * p<0.10, ** p<0.05, *** p<0.010.

6 The impact on firms and the real economy

Having established that the drop in lending observed in the second half of 2022 was also associated with the exposure to the sudden need to repay outstanding TLTROs, we move now to check whether exposure to the shock was also associated with effects on the real economy. To do this, we rely on firm characteristics from Orbis Europe, which is currently available until 2022. Thus, we can estimate the following model:

$$Y_f = \gamma \widehat{\text{Loan growth}}^{h=6}_{f,\text{July 2022}} + \xi \widehat{\alpha}^{h=6}_{f,\text{July 2022}} + \omega \overline{X}_f + \theta Z_f + \alpha_c + \varepsilon_f, \tag{2}$$

where Y_f is a measurement of a firm characteristic such as employment growth, investment both overall and in intangible assets, growth in firm liquidity, the growth rate in sales and the change in the amount of arrears. The main regressor is $\widehat{\text{Loan growth}}^{h=6}_{f,\text{July 2022}}$, which is the percentage change in loan volume (measured as the change in log-volumes) at the firm level between July 2022 and December 2022 as predicted by the exposure to the TLTRO shock. $\widehat{\alpha}^{h=6}_{f,\text{July 2022}}$ is the firm-time fixed effect $\alpha^h_{f,t}$ estimated with model (1) for the period $t =$ July 2022 and for the horizon $h = 6$, that is, corresponding to the loan growth from July to

December 2022. $\overline{X}_f$ are defined as weighted averages of bank characteristics at the firm level, with weights equal to the bank-firm exposures in June 2022. Z_f are firm characteristics measured in December 2021 (the latest available firm-level data before the shock), while α_c are country fixed effects that capture additional unobserved characteristics across firms not yet captured by loan demand estimates. Standard errors are clustered at the firm level.

Table 8: **Measuring real effects of TLTRO shock via credit supply in 2022**

Dependent variable:	(1) Employment growth	(2) Fixed investment	(3) Intangible investment	(4) Liquidity growth	(5) Sales growth	(6) Growth in arrears
Predicted decline in loan supply to firm	-0.020***	-0.094***	-0.053***	-0.060***	-0.003	0.019***
	(0.001)	(0.003)	(0.005)	(0.002)	(0.002)	(0.003)
Average bank-level controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm-level controls	Yes	Yes	Yes	Yes	Yes	Yes
Control for loan demand	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	360,250	357,085	177,433	360,963	360,257	339,770
R-squared	0.012	0.044	0.003	0.015	0.017	0.001

Notes: The table presents the estimates for γ of model (2). Each column represents the estimates for a regression of a different real firm-level dependent variable on the predicted decline in loan supply to firms due to the TLTRO shock, as estimated in the firm-time level regression of loan growth on the TLTRO shock, of which the results displayed in Column (5) of Table 4. All average bank-level controls are measured in June 2022. All firm-level controls are measured in end-2021. Standard errors are clustered at the firm level. See table A.3 for the coefficients on the control variables. * p<0.10, ** p<0.05, *** p<0.010.

Estimation results of equation (2) are displayed in Table 8.[16] These results imply that reduced lending due to the shock had a dampening impact on a range of firm outcomes. To gauge the impact on firm observables, we use the firm-level estimate of the impact on loan supply reported in Column (5) of Table 4. What is striking about the estimates is that most are statistically significant despite the fact that we are looking at an almost immediate impact, tracing the reaction of firm balance sheets from end-2021 to end-2022 to a shock that occurred in July 2022 and was transmitted to lending conditions in the following months. For this reason, and for the specificity of this well-isolated transmission channel, magnitudes remain contained for 2022, without excluding larger real effects unfolding in the following months as evidenced by the evidence on credit in Table 3. Each percentage point of lower loan supply through this channel, which roughly corresponds to the impact of one standard deviation of the TLTRO shock, led to a contraction of employment over 2022 of 2 basis points. Investment decreased by 9 basis points and investment in intangible assets by 5 basis points, signaling a likely impact on economic activity that could have lingered even further due to

[16] Table A.3 reports the estimated coefficients for all controls.

an impact on innovation and R&D. The contraction in credit associated with the TLTRO shock also shrank corporate liquidity by 6 basis points, which may have in turn contributed to the reduced willingness of firms to commit balance sheet capacity to longer-term assets. The reduction in operational capacity did not translate to a drop in sales, arguably on account of this being more the product of aggregate demand factors picked up by our controls and fixed effects. At the same time, a decreased willingness of banks to lend put firms in a tough spot in terms of their ability to conduct their ordinary business in an environment of rising interest rate payments, leading to an increased amount of loans that resulted in arrears by the end of 2022.

7 Conclusion

Our study highlights the implications of rapid central bank balance sheet reductions on the banking sector and the broader economy. By exploiting the recalibration of the ECB's TLTRO III in 2022, we provide robust evidence that a quick withdrawal of central bank liquidity can have tightening effects on bank credit. This increase in the effectiveness of the tightening impulse occurs as banks, accustomed to operating with ample liquidity, opt to swiftly adjust to a new environment where such reserves are rapidly reabsorbed. Consequently, both low-liquidity and high-liquidity banks experience a contraction in credit supply, albeit through different mechanisms, underscoring the pervasive impact of liquidity reductions irrespective of initial conditions. Importantly, our findings reveal that this contraction in credit supply can have effects on the real economy.

Overall, our research underscores the critical role of the pace and predictability of central bank balance sheet adjustments in influencing credit conditions and economic outcomes. By showing that faster adjustments in bank liquidity can indeed reduce bank credit and reach the real economy, the paper offers a bank credit perspective to the arguments in favour of the gradual and predictable manner in which central banks, such as the ECB, the Federal Reserve and the Bank of England, decided to reduce their balance sheets in normal times.

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A Appendix

Table A.1: **Impact of TLTRO shock on lending, with controls**

Dependent variable:	(1) Loan growth 12 months before	(2) Loan growth 6 months before	(3) Loan growth 6 months ahead	(4) Loan growth 12 months ahead	(5) Loan growth 18 months ahead
TLTRO shock	-3.796	0.189	-18.203*	-14.019***	-24.347***
	(4.687)	(4.138)	(10.675)	(4.815)	(6.510)
Assets (log)	0.029	0.043	-0.040	-0.109***	-0.229***
	(0.068)	(0.034)	(0.036)	(0.041)	(0.060)
Excess liquidity/Assets	0.143	-0.036	-0.135	-0.256*	-0.408**
	(0.117)	(0.127)	(0.103)	(0.130)	(0.196)
TLTRO funds/Assets	0.536**	0.099	-0.193	-0.135	-0.524
	(0.271)	(0.173)	(0.195)	(0.257)	(0.363)
Securities holdings/Assets	-0.302	0.021	-0.233	-0.175	-0.341
	(0.356)	(0.213)	(0.217)	(0.251)	(0.334)
Deposit ratio	-0.099	0.165	0.239	-0.027	-0.171
	(0.188)	(0.129)	(0.185)	(0.143)	(0.147)
NPL ratio	-0.004	0.330	0.077	0.146	-0.262
	(0.219)	(0.258)	(0.203)	(0.220)	(0.306)
CET1 ratio	-0.430	0.133	0.458	0.422	0.313
	(0.381)	(0.189)	(0.290)	(0.275)	(0.230)
Profitability	-3.164	0.735	2.826***	3.648*	5.974***
	(2.414)	(1.530)	(1.024)	(2.010)	(1.340)
Bank-firm FE	Yes	Yes	Yes	Yes	Yes
Firm-time FE	Yes	Yes	Yes	Yes	Yes
Observations	41,001,833	53,827,053	69,553,726	53,732,925	40,845,953
R-squared	0.657	0.534	0.533	0.653	0.704

Notes: The table presents the estimates for β^h for model (1), which is the coefficient in the regression at the bank-firm-time level loan growth from month t to month $t+h$ on the TLTRO shock. Each column represents a separate regression on a different horizon h, for $h = -12, -6, 6, 12, 18$. Bank controls include bank assets, excess liquidity over assets, TLTRO funds over assets, securities holdings over assets, deposits over liabilities, the NPL ratio, the CET1 ratio and return on assets. Standard errors are clustered at the bank and post-shock level. See Table A.1 for the coefficients on the control variables. * p<0.10, ** p<0.05, *** p<0.010.

Table A.2: **Impact of alternative TLTRO shock on lending, with controls**

Dependent variable:	(1) Loan growth 6 months before	(2) Loan growth 6 months ahead
Alternative TLTRO shock	2.107	-12.470*
	(2.686)	(7.190)
Assets (log)	0.043	-0.037
	(0.034)	(0.034)
Excess Liquidity/Assets	-0.037	-0.130
	(0.127)	(0.103)
TLTRO III/Assets	0.097	-0.197
	(0.173)	(0.197)
Securities holdings/Assets	0.020	-0.227
	(0.213)	(0.215)
Deposit ratio	0.167	0.238
	(0.129)	(0.187)
NPL ratio	0.331	0.054
	(0.256)	(0.194)
CET1 ratio	0.135	0.457
	(0.189)	(0.289)
Profitability	0.734	2.786***
	(1.530)	(1.011)
Bank controls	Yes	Yes
Bank-firm FE	Yes	Yes
Firm-time FE	Yes	Yes
Observations	53,827,053	69,553,726
R-squared	0.534	0.533

Notes: The table presents the estimates for β^h for an alternative to model (1) where TLTRO shock$_{b,t}$ is defined as the interaction between the same TLTRO shock$_b$ and an alternative dummy Post$_t$ that takes value 1 in July 2022 only and 0 in the months before and after. Each column represents a different horizon h, for $h = -6, 6$. Standard errors are clustered at the bank and post-shock level. * p<0.10, ** p<0.05, *** p<0.010.

Table A.3: **Measuring real effects of TLTRO shock via credit supply in 2022, with controls**

Dependent variable:	(1) Employment growth	(2) Fixed investment	(3) Intangible investment	(4) Liquidity growth	(5) Sales growth	(6) Growth in arrears
Predicted decline in loan supply to firm	-0.020***	-0.094***	-0.053***	-0.060***	-0.003	0.019***
	(0.001)	(0.003)	(0.005)	(0.002)	(0.002)	(0.003)
Average banks' Assets (log)	0.004***	0.008***	-0.005	0.001	0.005***	0.000
	(0.001)	(0.002)	(0.005)	(0.002)	(0.001)	(0.002)
Average banks' Excess Liquidity/Assets	0.026	0.009	0.075	0.056**	-0.008	0.090***
	(0.019)	(0.033)	(0.084)	(0.026)	(0.025)	(0.029)
Average banks' TLTRO funds /Assets	0.010	0.150***	0.102	0.006	0.086**	0.021
	(0.030)	(0.046)	(0.111)	(0.037)	(0.039)	(0.044)
Average banks' Securities holdings/Assets	0.013	0.111***	-0.114	0.004	0.014	0.040*
	(0.017)	(0.026)	(0.070)	(0.021)	(0.021)	(0.022)
Average banks' Deposit ratio	0.005	-0.025	-0.120***	-0.016	0.031**	-0.059***
	(0.012)	(0.020)	(0.046)	(0.016)	(0.016)	(0.018)
Average banks' NPL ratio	0.100**	0.059	0.513***	0.139***	0.016	0.007
	(0.043)	(0.072)	(0.148)	(0.048)	(0.054)	(0.104)
Average banks' CET1 ratio	-0.113***	-0.021	-0.161*	-0.162***	-0.224***	-0.107***
	(0.027)	(0.034)	(0.093)	(0.044)	(0.028)	(0.025)
Average banks' Profitability	0.630**	2.110***	-2.084*	1.399***	0.637*	-0.217
	(0.265)	(0.432)	(1.100)	(0.343)	(0.345)	(0.415)
Firm ROA	0.275***	0.511***	0.089***	0.230***	-0.145***	-0.039***
	(0.005)	(0.010)	(0.021)	(0.007)	(0.007)	(0.008)
Firm leverage	0.038***	0.018***	-0.029***	-0.003	0.103***	0.028***
	(0.002)	(0.003)	(0.008)	(0.003)	(0.003)	(0.003)
Firm liquidity	-1.685***	24.189***	2.883***	-8.593***	-6.393***	0.652**
	(0.197)	(0.288)	(0.319)	(0.771)	(0.263)	(0.296)
Estimated firm loan demand	-0.003***	-0.005***	-0.004	-0.004***	-0.004***	0.003***
	(0.001)	(0.001)	(0.003)	(0.001)	(0.001)	(0.001)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	360,250	357,085	177,433	360,963	360,257	339,770
R-squared	0.012	0.044	0.003	0.015	0.017	0.001

Notes: All average bank-level controls are measured in June 2022. All firm-level controls are measured in end-2021. The predicted decline in loan supply to firm is the predicted value for the growth rate of loan betweeen July 2022 and December 2022 from Table 4, Column (5). The estimated firm loan demand is the same control as in that specification, estimated in Table 3, Column (3). Standard errors are clustered at the firm level. * p<0.10, ** p<0.05, *** p<0.010.

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