Journal of Financial Economics

Central bank liquidity reallocation and bank lending: Evidence from the tiering system☆

Carlo Altavilla [a], Miguel Boucinha [b], Lorenzo Burlon [b], Mariassunta Giannetti [c,*], Julian Schumacher [b]

[a] European Central Bank and CEPR, Germany
[b] European Central Bank, Germany
[c] Stockholm School of Economics, the Swedish House of Finance, CEPR, and ECGI, Sweden

ARTICLE INFO

JEL classification:
G2
E5

Keywords:
Money market
Excess reserves
Transmission mechanism
Bank lending
Negative interest rate policy

ABSTRACT

We document that the reallocation of central bank reserves towards banks with higher liquidity needs fosters credit supply. Exploiting the ECB's tiered reserve remuneration system for identification, we show that this system encouraged banks with low reserve holdings to obtain more reserves through the money market. Concomitantly, these banks reduced their securities holdings and extended more credit. We estimate that the reallocation of one euro of reserves towards banks with ex ante low reserve holdings resulted in an increase in credit supply of about 15 cents.

1. Introduction

Central bank reserves represent the ultimate safe asset for banks due to their unwavering domestic value, even in times of crisis. No other asset in the economy offers the same level of safety and liquidity. Even highly rated government bonds carry market risk, as highlighted by the recent collapse of Silicon Valley Bank and the resulting tensions in the US banking system. Since central banks can issue reserves nearly cost-free, some argue that they should be created in ample quantities (Logan, 2023; Friedman, 1969).

However, the effects of central bank reserves on bank lending remain widely debated and are particularly important to study as central banks pursue quantitative tightening, which will significantly reduce the reserves held by financial institutions. On the one hand, the exceptional liquidity insurance provided by reserves may encourage lenders to expand credit supply . On the other hand, the risk-free income from remunerated reserves could crowd-out lending. Which of these effects prevails in practice remains an open question.

☆ Philipp Schnabl was the editor for this article. We thank the editor, an anonymous referee, Adrien d'Avernas, Will Diamond, Durrell Duffie, Diana Bonfim, Guillaume Horny, Amy Wang Huber, and seminar and conference participants at the American Economic Association Annual Meeting, the American Finance Association Annual Meeting, the 17th New York Fed / NYU Stern Conference on Financial Intermediation, the BIS Conference on Banks' liquidity in volatile macroeconomic and market environments, the European Finance Association, the Banque de France Workshop on New challenges for monetary policy and financial stability, the Banca d'Italia Conference on Monetary Policy in Exceptional Times, the ECB Conference on Money Markets, the Bank of Greece, EPFL/HEC Lausanne, the Bank of Portugal, the Federal Reserve Bank of Richmond, the National Bank of Belgium, the Riksbanken, the Swiss National Bank, the University of Luxembourg, and the University of Southampton for comments. Giannetti gratefully acknowledges financial support from the Jan Wallander and Tom Hedelius Foundation and the Riksbankens Jubileumsfond. Lorenzo Ferrante and Marc Agustí I Torres provided helpful research assistance. This paper was initially distributed with the title "Money Markets and Bank Lending". The opinions in this paper are those of the authors and do not necessarily reflect the views of the European Central Bank or the Eurosystem.

Received 9 March 2024; Received in revised form 25 March 2025; Accepted 30 March 2025
Available online 3 April 2025

This paper contributes to this emerging debate by showing that the relationship between reserves and credit supply depends on their distribution within the banking system. Specifically, we find that excess reserves stimulate bank lending if they are held by banks with *ex ante* low reserve holdings, as the increased liquidity enhances their ability to insure against liquidity shocks.[1]

We exploit a quasi-natural experiment related to a policy of the European Central Bank (ECB) that introduced a tiering system for remunerating excess reserve holdings. The policy increased the marginal return on reserves for banks with *ex ante* low reserve holdings. This specific feature of the policy led banks with previously low excess reserve holdings to accumulate more liquidity for reasons that were orthogonal to shocks to their clients' credit demand. Controlling for the potential effects of concurrent policies and credit demand, we show that banks receiving reserves expanded their credit supply more than those transferring reserves, whose loan supply remained unchanged. We conjecture that banks with *ex ante* high reserve holdings had reached their reserve satiation point. As a result, they transferred reserves without demanding higher interest rates or reducing credit supply to the corporate sector. Under this assumption, we estimate that the reallocation of reserves towards banks with higher liquidity needs, driven by the tiering system, boosted the aggregate supply of credit.

Our analysis proceeds in two steps. First, we document that the tiering system created plausibly exogenous incentives for a subset of banks to increase their reserve holdings. Specifically, the tiering system exempted a share of excess liquidity (reserve) holdings from the application of the negative deposit facility rate (DFR) with the aim of supporting the bank-based monetary policy transmission while preserving the positive contribution of the negative interest rate policies (NIRPs) to the accommodative policy stance. Crucially, the allocation of these exemptions was unrelated to banks' individual *ex ante* reserve holdings. This allows us to study an exogenous increase in the marginal value of excess reserves for banks with "unused allowances" (i.e., banks that *ex ante* held less liquidity than they could exempt from negative rates). By design, these banks had lower *ex ante* reserves holdings but began accumulating more reserves due to the tiering system. As a result, the ECB intervention facilitated a reallocation of excess liquidity from banks with high reserve holdings towards those with greater liquidity needs.

We show that the reserve reallocation primarily took place through the money market. Following the implementation of the tiering system, banks with unused allowances increased their net borrowing in the money market without facing a higher interest rate or maturity rationing. Meanwhile, banks with high excess liquidity holdings disproportionately increased their money market loans to banks with unused exemptions, relative to other banks.

In the second step of our analysis, we show that banks that increased their reserve holdings to fill their unused exemptions increased the supply of credit to the real sector. They also granted loans at lower rates and with longer maturity. These results are obtained controlling for credit demand shocks by either using interactions of firm and time fixed effects, following Khwaja and Mian (2008), or interacting industry, location, borrower size, and time fixed effects. In addition, significant differences in the behavior of banks with unused exemptions emerge after the tiering implementation. The granularity of our data also allows us to evaluate alternative mechanisms associated with the tiering adoption and the response of banks with high excess liquidity and high tiering savings, and to control for the effects of other policy measures, such as the negative interest rate policy (NIRP), the exposure to the ECB's asset purchase program (APP), and the targeted longer-term refinancing operations (TLTROs). We find no evidence that these alternative channels confound the impact of reserve reallocation on credit supply. Furthermore, we show that banks without unused exemptions, including those with *ex ante* high excess liquidity and higher tiering savings, did not alter their lending policies.

Taken together, our results suggest that reallocating liquidity towards banks with higher liquidity needs increases the willingness of previously liquidity-constrained banks to extend loans. We provide several additional pieces of evidence supporting this hypothesis. First, with the help of a simple framework, we show that if the uneven distribution of reserves had indeed reduced the credit supply, the banks with unused exemptions that responded more to the tiering implementation should have had *ex ante* higher cost of funding. We show that our results are indeed driven by banks with unused allowances and high funding costs. Before the implementation of the tiering system, high-funding-cost banks optimally held less reserves because the reserve returns were too low compared to their cost of capital. Consequently, high-funding-cost banks (including banks with higher borrowing rates prior to the implementation of the system, banks with low capitalizations, and banks with high CDS spreads) remained less insured against liquidity shocks through their reserve holdings and extended less credit.

Second, we show that financially constrained banks with unused exemptions committed more credit lines in response to the increased liquidity. Since credit lines involve hard-to-predict liquidity needs for the lender (Cooperman et al., 2022), this result suggests that banks' precautionary behavior diminished thanks to higher reserve holdings. Furthermore, we show that banks with unused allowances also reduced their government bond holdings.[2] Since sovereign bonds can be mobilized as collateral in secured money market transactions and are more liquid than bank loans, but are not as liquid as reserves, net bond sales indicate that these banks were hoarding less collateral. This behavior is consistent with improved liquidity insurance associated with higher reserve holdings.

Finally, we explore whether the increased propensity to take risk of banks that obtained more reserves led them not only to expand the supply of credit but also to misallocate credit by lending to riskier borrowers. We find no evidence that this is the case.

We contribute to a growing literature exploring the transmission mechanism of central banks' large-scale asset purchases. Existing literature has mainly explored the general equilibrium effects of quantitative easing by focusing on the reaction of asset prices (Krishnamurthy and Vissing-Jorgensen 2011), the transmission mechanism through long-term interest rates and mortgage origination (e.g., Chakraborty et al., 2020; Di Maggio, Kermani, and Palmer, 2020; Drechsler et al., 2024), or the effects of the capital gains generated by banks' security holdings (e.g., Acharya et al., 2019). An emerging strand of this literature explores whether the reserves created by central banks' large-scale asset purchases crowd in or crowd out bank lending, with mixed findings. During periods of quantitative easing, Acharya et al. (2023) find that banks with higher excess reserve holdings grant more credit lines and take excess risk (see also Acharya and Rajan, 2023). Relatedly, Rodnyansky and Darmouni (2017) and Kandrac and Schlusche (2021) show that banks that increased their reserve holdings, following the third round of quantitative easing by the Federal Reserve Board, increased lending. Much of the existing literature focuses on changes in the outstanding amount of reserves, which may influence lending by affecting the valuations of banks' security holdings, which rise when the central bank purchases securities and creates reserves. To focus on reserve holdings, Diamond, Jiang, and Ma (2024) estimate a model for deposit and loan demand exploiting exogenous variation from natural disasters. Given the estimated elasticities of loan and deposit demand, their counterfactual analysis implies that an increase in reserve holdings

[1] Concerns about the consequences of uneven distribution of excess liquidity across banks in the euro area have been raised also in the policy discourse (see e.g., Lane 2023).

[2] In work that was distributed subsequently to our paper and using less granular data that do not allow to identify the demand and supply for reserves, Baldo et al. (2022) study how banks adjusted their balance sheets to achieve higher liquidity holdings and provide evidence consistent with our findings.

crowds out lending. Thanks to the tiering system, we are able to focus on changes in the distribution of reserve holdings while controlling for the general equilibrium effects highlighted in previous literature. In addition, we benefit from plausibly exogenous variation in the reserve demand. Consistent with our theoretical framework, we find that banks increasing their reserve holdings tend to reduce their security holdings. Consequently, they can supply more credit without expanding their assets and facing a higher interest rate in the money market. We therefore estimate that reserve holdings have a positive effect on lending.[3] More importantly, we show that the distribution of reserves is as important as the aggregate amount of reserves for bank lending, even when reserves are abundant and policy rates are low.

2. Data sources

We rely on a wide array of data sources. Our main source to explore bank lending in the euro area is Anacredit, a credit register maintained by the European System of Central Banks, which includes harmonized transaction-level data for euro area banks. All banks report any loan provided to firms if the exposure to the borrower exceeds EUR 25,000.

From Anacredit, we obtain information on banks, their outstanding exposures to borrowers, as well as loan characteristics. The sample consists of a panel of 122 banks and 2,624,856 firms, for a total of 3,439,580 bank-firm relations, from September 2018 to February 2020 (18 months). Firms are distributed across 19 countries (Austria, Belgium, Cyprus, Germany, Estonia, Spain, Finland, France, Greece, Ireland, Italy, Lithuania, Latvia, Luxembourg, Malta, The Netherlands, Portugal, Slovenia, and Slovakia), 89 2-digit NACE industries, and 1055 NUTS2 locations. We further partition borrowers into size deciles based on their outstanding bank liabilities during the previous month. This provides us with 3,087,276 industry-location-size-month clusters. The large number of clusters available, together with the fact that many borrowers have multiple bank relationships, helps us in the identification of the credit supply.

We complement Anacredit with bank level information from the Individual Balance Sheet Indicators (IBSI), another proprietary database maintained by the ECB, which allows us to follow the main asset and liability items of 128 banks resident in the euro area at monthly frequency. This dataset provides information on the amount of outstanding loans, household and corporate deposits, and other relevant bank balance sheet information. Information on each bank's borrowing in targeted longer-term refinancing operations (TLTROs) is collected from the ECB's proprietary liquidity data. We also obtain banks' stock prices and CDS spreads from Thomson Reuters.

In addition, we explore bank behavior in the money market using the Money Market Statistical Reporting (MMSR) data. These data are collected to provide information on the transmission of monetary policy to the money market. Around 50 large banks from across the euro area are required to submit a detailed list of all money market transactions daily. The dataset has been collected since July 2016 and covers all secured and unsecured transactions by the reporting banks with banks and non-banks with maturity of up to twelve months. It comprises around 30 million transactions in the secured (repo) market and around 12 million transactions in the unsecured market during our sample period. In our empirical analysis, we aggregate the individual outstanding transactions at the reporting-bank level or at the reporting-bank and counterparty (relationship) level to create a daily panel of the stock of outstanding money market transactions.

Table 1 provides variable definitions and summary statistics.

[3] In addition, we focus on a period with abundant liquidity in which shocks to liquidity demand are not expected to affect money market rates (e.g., Afonso et al. 2024). Diamond et al. (2024) consider a long time series, including periods with scarce reserves, which may influence their estimate of the changes in banks' balance sheet size on their cost of capital.

3. Implementation of the tiering

Tiering systems insulate a part of a bank's reserve holdings from the level of a central bank's main policy rate and are most often introduced when policy rates are negative.[4] In other words, a tiering system for reserve remuneration exempts some proportion of banks' excess liquidity from negative rates and can introduce substantial savings for the banking system.

The possible adoption of a tiering system in the euro area was first hinted at on March 27, 2019, in a speech by then-ECB president Mario Draghi. After almost five years of negative interest rates, analysts had increasingly voiced concerns about the possible adverse side effects on bank profitability. The speech by Draghi represented the first mention of specific measures to contain the potential side effects of the NIRP by an ECB policymaker: "*if necessary, we need to reflect on possible measures that can preserve the favourable implications of negative rates for the economy, while mitigating the side effects, if any*" (Draghi, 2019).

A news report published a few hours after the speech further buoyed market expectations by claiming that the ECB was preparing to introduce a tiering system.[5] This information triggered a sharp market reaction: As shown in Fig. 1 using high-frequency data, euro area bank stocks jumped by almost 3 % upon the news release, considerably outperforming a broader market index.

The ECB's Governing Council formally decided on the introduction of a tiering system and the actual size of the exemptions on September 12, 2019, together with an interest rate cut from −0.40 % to −0.50 %. The tiering system exempted excess liquidity holdings of up to six times banks' minimum reserve requirements (MRR) from the application of the negative DFR. This design recognized that banks' needs for liquidity are proportional to their deposits, which in turn determine minimum reserve requirements. Thus, the banks with unused exemptions were banks with low excess reserves *ex ante*. Importantly, the relevant cut-off dates for determining the minimum reserve requirements (and therefore the tiering allowances) until October 2019 were July 2019 (for banks reporting monthly) or June 2019 (for banks reporting quarterly). The dates were, therefore, predetermined relative to the announcement.

To avoid an unintended tightening in bank funding conditions, the tiering system was calibrated such that the "non-exempted tier" – the amount of excess liquidity that remained subject to negative interest rates – was sufficiently large to avoid upward pressure on money market rates, thus ensuring that the monetary policy stance was not tightened.

The ECB's tiering system started operating on October 30, 2019, in accordance with the September announcement and remained in place until the ECB lifted interest rates into positive territory in September 2022.

In what follows, we examine how a change in the marginal rate on excess reserves holdings affects banks' asset composition and credit supply with the introduction of the tiering. In Section 6, we discuss how we control for the fact that the tiering announcements coincided with other policy measures – notably a further interest rate cut – and were interpreted by market participants as a signal to maintain or lower interest rates for an extended period.

[4] Switzerland has maintained a tiering system also after abandoning the NIRP. Concurrent work by Fuster, Schelling and Towbin (2021) shows that in Switzerland after the introduction of the tiering, banks that benefitted most from the increase in the exemption threshold charged higher loan spreads, took less risk, and obtained liquidity by increasing the interest rate on deposits, effectively lowering the pass-through of policy easing. Our paper focuses on the larger and heterogenous money market of the euro area and shows that when the distribution of reserves is *ex ante* skewed towards banks that are likely to have reached their satiation point, tiering systems, by increasing the benefits of trading, can stimulate bank lending.

[5] Reuters, "ECB studying tiered deposit rate to alleviate banks' plight", March 27, 2019, released at 13h25.

Table 1
Summary statistics
Panel A summarizes the bank level dataset. We report observations at the bank and month level. Our sample consists of a panel of 128 banks from January 2014 to February 2020 (74 months). Panel B summarizes the Anacredit sample. We report observations at the bank, firm and month level. The Anacredit sample consists of a panel of 122 banks and 2,624,856 firms, for a total of 3,439,580 bank-firm relations, from September 2018 to February 2020 (18 months). Firms are distributed across 19 countries (AT, BE, CY, DE, EE, ES, FI, FR, GR, IE, IT, LT, LU, LV, MT, NL, PT, SI, SK), 89 2-digit NACE industries and 1,055 NUTS2 locations, providing 3,087,276 industry-location-size-month fixed effects. Panel C summarizes the MMSR sample.

Panel A. Bank-month level sample

Variable name	Units	Definition	Obs.	Mean	St. Dev.
Monthly change in NFC loans	p.p.	Monthly change in ratio of NFC loans over assets.	9325	−0.004	0.878
Monthly change in excess liquidity	p.p.	Monthly change in ratio of excess liquidity (current account plus deposit facility minus minimum reserve requirements) over assets	9325	0.103	1.333
Monthly change in holdings of government securities	p.p.	Monthly change in ratio of holdings of government bonds over assets.	9325	−0.012	0.418
Exposure(Feb 2019)	%	Unused exemption allowance, i.e., difference of 6 fold the minimum reserve requirement and the excess liquidity holdings of bank in February 2019 if such difference is positive, and to zero otherwise. It is expressed in percentage of main assets.	9325	0.879	1.480
Exposure(Oct 2019)	%	Unused exemption allowance, i.e., difference of 6 fold the minimum reserve requirement and the excess liquidity holdings of bank in October 2019 if such difference is positive, and to zero otherwise. It is expressed in percentage of main assets.	9325	0.841	1.446
Interim(Mar-Oct 2019)	Cat.	Dummy variable equal to 1 if t is between March 2019 and October 2019, 0 otherwise.	9325	0.110	0.313
Implementation(Nov 2019-Feb 2020)	Cat.	Dummy variable equal to 1 if t is between November 2019 and February 2020, 0 otherwise.	9325	0.055	0.227
CDS	p.p.	5-years credit default swaps, in percentage points. One month lag.	9325	1.356	2.072

Panel B. Bank-firm-month level sample

Variable name	Units	Definition	Obs.	Mean	St. Dev.
Volume of NFC loans	log(EUR mln)	Logarithm of outstanding amounts (in EUR million) of loans between a bank and a firm in a given month.	36,163,821	−2.318	1.954
Exposure(Feb 2019)	p.p.	Unused exemption allowance, i.e., difference of 6-fold the minimum reserve requirement and the excess liquidity holdings of a bank in February 2019 if such difference is positive, and zero otherwise. It is expressed in percentage of main assets.	52,814,649	0.648	1.130
Exposure(Oct 2019)	p.p.	Unused exemption allowance, i.e., difference of 6-fold the minimum reserve requirement and the excess liquidity holdings of a bank in October 2019 if such difference is positive, and zero otherwise. It is expressed in percentage of main assets.	52,814,649	0.520	0.913
Interim(Mar-Oct 2019)	0/1	Dummy variable equal to 1 between March 2019 and October 2019, 0 otherwise.	52,814,649	0.438	0.496
Implementation(Nov 2019-Feb 2020)	0/1	Dummy variable equal to 1 between November 2019 and February 2020, 0 otherwise.	52,814,649	0.228	0.420
Tiering Benefits (Feb 2019)	p.p.	Savings that would have stemmed from holdings of excess liquidity in February 2019 under the tiering, expressed as a ratio of assets, that is, $100 \times [\min\{0, DFR \times (EL - MRR \times 6)\} - DFR \times EL]/\text{Assets}$.	52,814,649	0.023	0.021
Tiering Benefits (Oct 2019)	p.p.	Savings that would have stemmed from holdings of excess liquidity in October 2019 under the tiering, expressed as a ratio of assets, that is, $100 \times [\min\{0, DFR \times (EL - MRR \times 6)\} - DFR \times EL]/\text{Assets}$.	52,814,649	0.024	0.019
CDS	p.p.	5-years credit default swaps, in percentage points. One month lag.	52,814,649	1.050	1.182
Excess liquidity	%	Ratio of excess liquidity (current account + deposit facility - minimum reserve requirements) over main assets. One month lag.	52,814,649	4.705	3.754
Holdings of government securities	%	Ratio of holdings of securities issued by general governments over main assets. One month lag.	52,814,649	6.613	4.826
Deposit ratio	%	Ratio of deposits from NFCs and households over main liabilities. One month lag.	52,814,649	37.724	21.050
TLTRO funds	%	Ratio of TLTRO uptake over main liabilities. One month lag.	52,814,649	4.212	4.169
Lending rate	% p.a.	Lending rate on outstanding amounts (in % per annum) on loans between a bank and a firm in a given month.	36,163,821	3.129	3.729
Maturity	Days	Residual maturity of loans between a bank and a firm in a given month.	36,163,821	1316	1665
Drawn credit lines	log(EUR mln)	Logarithm of drawn credit lines (in EUR million) between a bank and a firm in a given month.	21,321,876	−3.707	2.674
Undrawn credit lines	log(EUR mln)	Logarithm of granted but undrawn credit lines (in EUR million) between a bank and a firm in a given month.	18,085,424	−4.032	2.546
Overall credit lines	log(EUR mln)	Logarithm of granted (drawn and undrawn) credit lines (in EUR million) between a bank and a firm in a given month.	25,174,025	−3.003	2.362

Panel C. Bank daily panel of the money market transactions

Variable name	Units	Definition	Obs.	Mean	St. Dev.
Stock of outstanding secured borrowing transactions / MRR	Ratio	Stock of outstanding borrowing in the secured money market relative to a bank's minimum reserve requirement.	44,269	11.976	16.613
Stock of outstanding secured lending transactions / MRR	Ratio	Stock of outstanding lending in the secured money market relative to a bank's minimum reserve requirement.	44,269	9.776	17.967
Stock of outstanding secured net borrowing transactions / MRR	Ratio	Stock of net borrowing in the secured money market, defined as gross borrowing minus gross lending, relative to a bank's minimum reserve requirement.	44,269	2.200	13.076
Stock of outstanding unsecured borrowing transactions / MRR	Ratio	Stock of outstanding borrowing in the unsecured money market relative to a bank's minimum reserve requirement.	44,269	9.168	12.338

(*continued on next page*)

Table 1 (*continued*)

Panel C. Bank daily panel of the money market transactions					
Variable name	Units	Definition	Obs.	Mean	St. Dev.
Stock of outstanding unsecured lending transactions / MRR	Ratio	Stock of outstanding lending in the unsecured money market relative to a bank's minimum reserve requirement.	44,269	1.912	4.684
Stock of outstanding unsecured net borrowing transactions / MRR	Ratio	Stock of net borrowing in the unsecured money market, defined as gross borrowing minus gross lending, relative to a bank's minimum reserve requirement.	44,269	7.257	13.375
CDS spread	p.p.	5-years credit default swaps, in percentage points. Equal to domestic sovereign CDS spread for state-owned banks without issuer-specific CDS.	44,269	1.017	1.719
Interim period (26 Mar 2019 - 29 Oct 2019)	0/1	Dummy variable equal to 1 between 26 March 2019 and 29 October 2019, 0 otherwise.	44,269	0.197	0.398
Implementation (30 Oct 2019 - 28 Jan 2020)	0/1	Dummy variable equal to 1 between 30 October 2019 and 28 January 2019, 0 otherwise.	44,269	0.082	0.275
Exposure in Feb 2019	p.p.	Unused exemption allowance, i.e., difference of 6-fold the minimum reserve requirement and the excess liquidity holdings of a bank between 30 January and 12 March 2019 if such difference is positive, and zero otherwise. It is expressed in percentage of total assets.	44,269	0.493	1.013
Exposure in Oct 2019	p.p.	Unused exemption allowance, i.e., difference of 6-fold the minimum reserve requirement and the excess liquidity holdings of a bank between 18 September and 29 October 2019 if such difference is positive, and zero otherwise. It is expressed in percentage of main total.	44,269	0.426	0.828

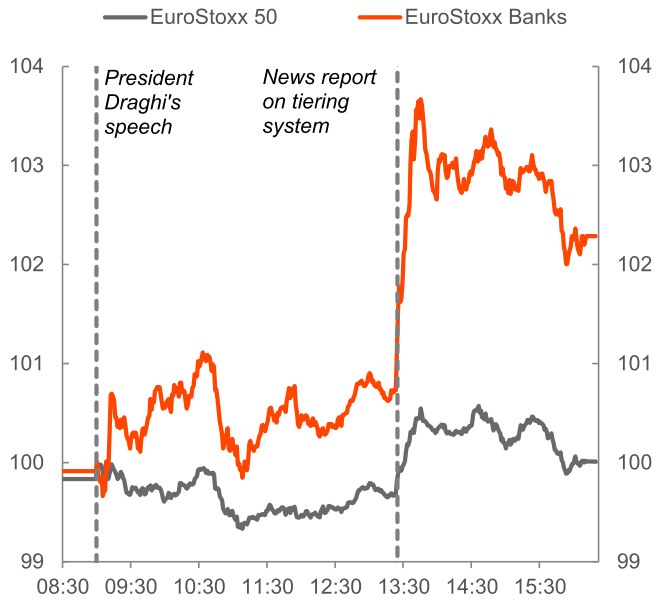

Fig. 1. Stock market reaction to the first mention of a tiering system
The chart shows the intraday development in the broad EuroStoxx50 index, as well as the narrow EuroStoxx Banks index on March 27, 2019, normalised to 100 at the start of trading at 9am. Former ECB president Draghi's speech containing a reference to "mitigating measures" to address the possible side effects of negative interest rates on bank profitability was released at 9:00 am in the morning and followed by an uptick in the EuroStoxx banks index of around 1 %, while the broader index remained largely unchanged. The release of a news bulletin reporting that the ECB was working on a tiering system at 13:25 was followed by an additional increase in banks' equity prices by around 2.5 %, compared to a rise of 0.7 % in the broader equity index.

4. Hypotheses on the effects of the tiering on bank asset composition

We describe a simple framework explaining how an asymmetric distribution of reserves can constrain the loan supply of banks with the lowest excess reserve holdings, without favoring credit extension by banks with high reserve holdings. To conceptualize this, we model the profit maximization of a bank that can hold reserves, securities, and loans and has a cost of capital that is determined outside the model.

Whether the distribution of reserves becomes more even because of changes in the demand or supply is immaterial for the effect on bank lending we aim to capture in our empirical analysis. However, since we focus on a period with vast amounts of excess liquidity, in which the ECB was ready to meet any demand for liquidity through its refinancing operations, the supply of liquidity can be thought as perfectly elastic. Therefore, we cast our conceptual framework focusing on the demand for reserves.

We think of reserves as providing unique liquidity services to the bank, similarly to Lopez-Salido and Vissing-Jorgensen (2023). Therefore, we assume that there is a complementarity between credit supply and reserves. The complementarity arises from the fact that loans are relatively illiquid, and additional illiquidity arising from more lending is mitigated by extra liquidity on the rest of the asset side when a bank holds more excess reserves (Rodnyansky and Darmouni 2017). This captures the idea that reserves may render bank runs less likely or at least reduce their costs. Consistent with Afonso et al. (2023), we also assume that there is a satiation point beyond which the marginal benefit of holding reserves is zero (or constant at a very low level).

Thus, excess reserves, besides yielding an interest rate *r(reserves)*, increase a bank's expected profits according to the following function, which can be thought as capturing the benefits of insuring expected liquidity shocks: $v(reserves,\ loans) > 0$, where $v_R > 0,\ v_{RR} \leq 0,\ v_L < 0,\ v_{LL} < 0,$ and $v_{RL} > 0$. Specifically, the function v must be thought as a bank's profits from extending credit, holding constant the quality of borrowers and their demand for credit (as we will do in the empirical analysis). While more loans can decrease a bank's expected profits because they expose it to higher expected costs from funding shocks, $v_{RL} > 0$ captures that reserves allow the bank to extend credit with lower expected costs arising from funding shocks. Because of the satiation point, $v_{RR} = v_{RL} = 0$ if $R > \overline{R}$.

For similar reasons to those discussed above, securities, which are far more liquid than loans, are second-best substitutes for reserves. Differently from reserves that can be used directly to fulfill cash demand needs, even safe securities – such as Treasuries or other highly-rated government bonds – need to be sold or pledged to be converted into cash. The tensions in the US banking system in 2023 are a stark reminder that even the highest quality assets cannot rival central bank reserves in liquidity value. To capture this, we assume that: $u(reserves,\ securities) > 0$, where $0 < u_R < v_R,\ u_{RR} \leq 0,\ u_S > 0,\ u_{SS} \leq 0,$ and $u_{RS} < 0$ as long as if $R < \overline{R}$; $u_{RR} = u_{RS} = 0$ if $R > \overline{R}$. While more illiquid than reserves, securities have higher yields, and for this reason, they may be preferred by banks with high cost of capital.

A bank's profits can be written as:

$$\pi = r(reserves)\ Reserves + r(securities)\ Securities + r(loans)\ Loans + v(reserves, loans) + u(reserves, securities) - cost\ of\ capital * Liabilities$$

where $Liabilities = Reserves + Securities + Loans$.

The first-order conditions are:

$$r(reserves) + v_R + u_R - cost\ of\ capital = 0,$$

$$r(loans) + v_L - cost\ of\ capital = 0,$$

$$r(securities) + u_S - cost\ of\ capital = 0.$$

Consider a bank with relatively high cost of capital. From the first-order condition for reserves, assuming that the return on reserves and the cost of capital are exogenously given, it follows that such a bank finds it optimal to have relatively lower reserves (higher v_R). Also, for a given return on bank loans outstanding, such a bank will have a higher v_L and therefore fewer loans to satisfy the second first-order condition.

The introduction of the tiering system for a bank with low reserve holdings and unused exemptions is equivalent to an increase in the marginal interest rate on reserves, $r(reserves)$. Given the properties of v and u, and for given cost of capital, such a bank will increase its reserve holdings to satisfy its first-order condition (lower v_R). An increase in reserves implies an increase in the marginal benefit of issuing loans and a decrease in the marginal benefit of holding securities ($v_L\uparrow$ $u_S\downarrow$). Thus, given our assumptions on v and u, the first-order conditions imply that a bank with *ex ante* low reserve holdings and unused exemptions will reduce its security holdings and increase the supply of credit.

While securities can be held by unregulated financial intermediaries, reserves must be obtained from other banks that have high reserve holdings and have presumably reached their satiation point, which, consistently with the design of the policy, we assume to be well above the exemptions granted by the tiering. Banks that have reached their satiation point are indifferent on the amount of reserves (and securities) to hold (v_R and u_S do not depend on the level of reserves). They will thus be willing to transfer reserves to banks with *ex ante* low reserve holdings and unused exemptions.

Note that the simple framework also implies that banks that have high reserve holdings and have reached their satiation point are expected to have low (marginal) cost of capital, which makes it optimal for them to hold excess reserves even if they have low returns and marginal benefits.

In what follows, we test whether banks whose marginal return on reserves increases indeed decrease their security holdings and expand the supply of credit.

5. The redistribution of reserves following the tiering system

5.1. Ex ante distribution of reserves and changes in reserve holdings

Changes in a bank's liquidity holdings are typically endogenous and reflect bank-specific shocks, complicating any empirical assessment of the role of reserve holdings on banks' behavior. This section shows that the tiering system, however, introduced exogenous variation in the reallocation of reserves across banks.

To maximize the value of the exemptions introduced with the tiering system, all banks needed to hold at least as much liquidity as is exempt from paying negative rates. The marginal value of liquidity thus increased only for banks with unused exemptions, which became inclined to hold more reserves even if they faced higher cost of capital. The marginal returns on reserves did not change for banks with *ex ante* high liquidity holdings.

Table IA.1 describes the characteristics of banks with unused exemptions above and below the median, which corresponds to banks that fulfill all their exemptions. Panel A considers a bank's unused exemptions relative to its total assets as of October 2019, when the policy was about to be implemented (October 2019 Exposure). Panel B considers a notional exposure to the policy in February 2019, shortly before the possibility of the tiering was first hinted, when the size of the exemptions and the actual implementation of the tiering were still uncertain. The determinants are the same for both variables and are consistent with our conceptual framework. Specifically, banks with high unused exemptions have, by construction, lower excess liquidity holdings relative to their assets. More importantly, they have ex ante higher CDS spreads, which is consistent with a higher cost of capital depressing the demand for low-return assets, like reserves. Facing a higher interest rate in the money market, high-exemption banks make less use of wholesale funding, as indicated by a higher deposit ratio and higher use of the targeted long-term refinancing operations (TLTRO funds). As our model implies, before the policy implementation, high-exposure banks have higher securities holdings, which are an imperfect substitute for excess reserves in insuring against adverse liquidity shocks. We observe no statistically significant differences in bank capital and assets between banks with unused exemptions and other banks. Overall, our conceptual framework in Section 4 provides a realistic representation of why some banks chose to have low reserve holdings before the tiering implementation and confirms that differences in creditworthiness and cost of capital are important determinants.

Fig. 2 provides evidence that unused allowances are indeed associated with an increase in banks' reserve holdings following the tiering implementation. It describes how the distribution of excess liquidity relative to exemptions changed. Unused exemption allowances declined swiftly to low levels as banks attracted sufficient reserves from banks over-fulfilling the allowance.[6] Since the exemptions are a multiple of the required reserve holdings, they reflect the liquidity needs of banks with different sizes and capital structure. The figure thus shows that after the tiering adoption the reserve distribution became more even, because reserves were reallocated towards banks with higher liquidity needs. Importantly, changes in the distribution of liquidity before November 2019 were minimal, indicating that banks' unused exemptions in October 2019 largely reflect their excess liquidity holdings before the tiering system was announced.

The descriptive evidence holds up when we control for banks' CDS spread, bank fixed effects and country specific shocks. We estimate the following equation:

$$\begin{aligned}\Delta \frac{\text{Excess Liquidity}_{ict}}{\text{Assets}_{ict}} = {} & \beta_1 \left(\text{Interim}_t \times \text{Exposure}_i^{Feb\ 2019}\right) \\ & + \beta_2 \left(\text{Implementation}_t \times \text{Exposure}_i^{Oct\ 2019}\right) \\ & + \beta_3 CDS_{it} + \alpha_i + \alpha_{ct} + u_{ict}, \end{aligned} \quad (1)$$

where the dependent variable is the monthly change in excess liquidity of bank i from country c, which we normalize by assets to abstract from the effect of bank size. The variable $\text{Exposure}_i^{Oct\ 2019}$ captures that banks with less excess liquidity than their tiering allowance in October 2019, when the tiering was introduced, are more exposed to the tiering system because they have a higher marginal return on reserve holdings than other banks and therefore stronger incentives to acquire liquidity. It is defined as bank i's unused allowance, relative to total assets, $\max\left(\frac{\text{Allowance}_i - \text{Excess liquidity}_i}{\text{Total assets}_i}, 0\right)$ We also compute a notional exposure in March 2019, $\text{Exposure}_i^{Feb\ 2019}$, when the tiering was first discussed to evaluate to what extent banks started to adapt earlier. Specifically, since the amount of excess reserves that were exempt from negative rates under the tiering system were evaluated based on the average reserve holdings between the monetary policy meetings of the ECB's Governing Council, the so-called maintenance periods, we compute excess liquidity holdings during the maintenance periods preceding President Draghi's speech in March 2019 (from 30 January to 12 March) as well as the one

[6] Banks "compliance" with the tiering system was near-universal. At the end of the first maintenance period after the implementation of the tiering, banks' unused allowances were only 0.9%, an amount that declined to 0.8% at the end of the subsequent maintenance period.

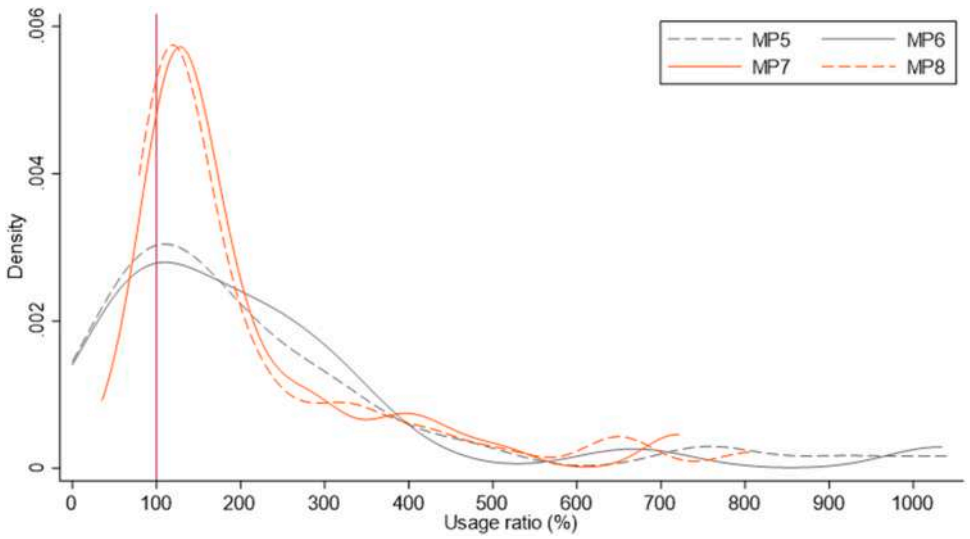

Fig. 2. The distribution of excess liquidity between banks before and after the tiering
The figure plots the distribution of the ratio of a bank's excess liquidity relative to the bank's exemptions equal to six times the MMR in the two maintenance periods before (MP5 and MP6) the tiering implementation in November 2019 and the two after (MP7 and MP8). MP5 goes between July 31, 2019 and September 17, 2019; MP6 between September 18, 2019 and October 29, 2019; MP7 between October 30, 2019 and December 17, 2019; and MP8 between December 18, 2019 and January 28, 2020.

before the actual implementation of the tiering system as of the end of October 2019 (from 18 September to 29 October). $Implementation_t$ is an indicator variable that captures the period during which the tiering system has been in place, and $Interim_t$ is equal to one between March and September 2019.

We include banks' CDS_{it} spreads to control for credit risk and allow for bank (α_i) as well as country-month ($\alpha_{c,t}$) fixed effects.

By including the notional exposure to the hypothetical tiering $Exposure_i^{Feb\ 2019}$, along with the actual $Exposure_i^{Oct\ 2019}$, we capture any adjustment in bank policies after the tiering was first hinted, before its implementation. Naturally, since a bank's reserve holdings depend not only on borrowing and lending decisions, but also on deposits and redemptions, which are outside its control, there is variation in reserve holdings between February and October 2019 even if, as shown by Figure IA.1, the correlation between the two exposures is high.

Table 2 shows the estimates of Eq. (1). Banks with lower liquidity holdings and consequently higher unused exemptions in expectation increase their holdings of excess liquidity during the period between March and October 2019. A one-standard-deviation (1.5 percentage points, pp) increase in (prospective) unused exemptions is associated with an increase in excess liquidity holdings by close to 12 bps of total assets. The increase in holdings of excess liquidity is three times larger after the tiering system was finally implemented in November 2019. The minimal adjustment of reserve policies during the interim period is rational for banks. Since this was a period with high excess liquidity in which it was easy to obtain liquidity, including from the ECB, banks had no reason to adopt pre-emptive behaviors, which would have been costly because of the negative rates before the actual phase-in of the tiering.

This evidence suggests that unused exemptions granting a higher marginal return on liquidity exogenously increased the demand for reserves of banks with *ex ante* low reserve holdings. In what follows, we shed more light on *how* the banks with unused allowances attracted the additional reserves using money market data. We also show that banks decreased their security holdings, as is consistent with our conceptual framework.

Table 2
Changes in excess liquidity
The table shows results from difference-in-differences regressions of banks' excess liquidity on exposure to the tiering system. The dependent variable in all columns is the bank's monthly change in the ratio of excess liquidity over assets. "Exposure(Feb 2019)" is equal to the unused exemption allowance (as a percentage of main assets) of bank *i* in February 2019 if such difference is positive, and to zero otherwise. "Exposure(Oct 2019)" is defined in the same way, but as of October 2019. The "Interim (Mar-Oct 2019)" variable is an indicator for the time between the speech by former ECB President Draghi on March 27, 2019, in which he hinted at the introduction of a tiering system for the first time, and the eventual implementation of the system as of October 30, 2019. "Implementation (Nov 2019-Feb 2020)" is an indicator variable for the time after October 30, 2019, i.e., the time since the tiering system has been in place. "CDS" represents banks' CDS spread (in percentage points); for state-owned banks in the sample, this is measured as the domestic sovereign CDS spread. The observation frequency in all regressions is monthly, and the sample period ranges from January 2014 to February 2020. Standard errors are clustered at the bank and country-time level. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1 %, 5 %, and 10 % level, respectively.

Dependent Variable: Monthly change in excess liquidity	(1)	(2)	(3)
Exposure(Feb 2019)	−0.059*		
	(0.031)		
Exposure(Feb 2019)*Interim(Mar-Oct 2019)	0.078**	0.078**	0.078**
	(0.030)	(0.030)	(0.030)
Exposure(Oct 2019)	0.035		
	(0.038)		
Exposure(Oct 2019)*Implementation(Nov 2019-Feb 2020)	0.224***	0.224***	0.224***
	(0.066)	(0.066)	(0.066)
CDS			0.023
			(0.015)
Country-month FE	Yes	Yes	Yes
Bank FE	–	Yes	Yes
Observations	9325	9325	9325
R-squared	0.166	0.178	0.178

5.2. Reserve holdings and the money market

This section shows that after the introduction of the tiering, banks

with low reserve holdings filled their unused exemptions (also) by borrowing through the money market. We consider both the secured and the unsecured money market segments.[7]

Before the introduction of the tiering, excess liquidity was largely held by banks in Germany, France, and The Netherlands. There was sporadic trading with the banks with lower liquidity holdings, mostly located in countries that were more affected by the sovereign debt crisis (Baldo et al., 2017; Eisenschmidt, Kedan, and Tietz, 2018). Facing relatively higher interest rates, low-excess-liquidity banks had limited ability to insure against liquidity risks through the money market.

5.2.1. Descriptive evidence

Fig. 3 shows how net borrowing in the money market changed following the tiering-related announcements distinguishing between the secured (Panel A) and unsecured (Panel B) market segments. The announcement of a new series of TLTROs as well as expectations for a restart of net asset purchases over the course of 2019 had reduced banks' need to trade in the money market for funding purposes (ECB 2021) and had led to a decline in trading activity in the secured market over the summer of 2019. Activity in both the secured and unsecured money market segments increased markedly in the period leading up to and following the actual implementation of the tiering system at the end of October 2019. While net borrowing by banks with unused allowances in the unsecured market increased gradually following the announcement of the tiering system in September, there was a much sharper increase in the secured market around October 30, when the exemptions became effective.[8]

Relating the increase in banks' money market borrowing to the change in their reserve holdings shows that the redistribution of liquidity was primarily intermediated through the secured and unsecured markets. Fig. 4 illustrates the change in banks' reserve holdings, distinguishing between banks with and without unused allowances, computed as of October 2019. Banks with unused allowances increased their reserve holdings by 55 % in November 2019 (the first month of the introduction of the tiering system) compared to August (the month before its announcement). 71 % of that increase was matched by higher net money market borrowing, especially in the secured segment. In contrast, banks without unused allowances shed around 14 % of their reserve holdings, 62 % of which can be linked to additional net lending in the money market. Neither group of banks significantly raised or lowered their borrowing from the ECB over the same period, suggesting that the money market was the primary conduit for the reallocation of liquidity following the introduction of the tiering system.

The redistribution of reserves and the increase in money market borrowing by banks with unused exemptions did not go along with a notable increase in money market interest rates. At the aggregate level, this reflected the ECB's intention to keep a sufficient amount of excess liquidity subject to the DFR to ensure that key money market rates would continue to be firmly anchored. But also at the individual bank level, interest rates on the flow of money market transactions hardly budged in response to the expansion in trading volumes, neither for banks with nor for banks without unused tiering allowances (Fig. 5). It appears that banks with unused exemptions, which were facing higher interest rates in the money market, optimally held low levels of reserves before the tiering introduction. These banks became more inclined to borrow from banks with high excess liquidity, thanks to the higher returns on the excess reserves guaranteed by the exemptions. Thus, the tiering, by increasing the marginal returns on reserves for banks with unused exemptions, favored the reallocation of liquidity from banks that had presumably reached their satiation point to banks with higher liquidity needs.

5.2.2. Multivariate analysis

To provide systematic evidence on how banks adjusted their liquidity positions in the money market, we analyse a daily panel of banks' money market activity, based on the transaction-level MMSR dataset. Specifically, we estimate the following specification:

$$\begin{aligned}\text{Money Market Activity}_{ictm} = {} & \beta_1\left(\text{Interim}_t \times \text{Exposure}_i^{Feb\ 2019}\right) \\ & + \beta_2\left(\text{Implementation}_t \times \text{Exposure}_i^{Oct\ 2019}\right) \\ & + \beta_3 CDS_{it} + \alpha_i + \alpha_{cm} + u_{ictm}\end{aligned} \tag{2}$$

where Money Market Activity$_{ictm}$ represents one of six alternative measures of bank i's from country c trading in the money market on day t in maintenance period m: gross borrowing, gross lending, or net borrowing, in either the secured or unsecured segment. Each of the variables is scaled by banks' minimum reserve requirements to express the coefficients in terms of the units of the tiering allowance. Interim$_t$, Implementation$_t$, Exposure$_i^{Feb\ 2019}$, and Exposure$_i^{Oct\ 2019}$ are defined as in the previous section. We include banks' CDS_{it} spreads to control for credit risk and allow for bank (α_i) as well as country-maintenance period (α_{cm}) fixed effects. Given the frequency at which the tiering benefits accrue, we expect correlation in the average money market activity of banks during a maintenance period and, for this reason, we cluster standard errors at the bank and maintenance period level.

In line with the descriptive evidence, Table 3, Panel A shows that banks with unused tiering allowances started to borrow more once the system was implemented. Specifically, in column (3), a one-percentage point larger unused allowance as of October 2019 (expressed as a share of total assets) is associated with an increase in net secured borrowing amounting to 1.7 times the banks' reserve requirements after the actual implementation of the system. We do not observe significant changes in gross borrowing, and the adjustment in gross lending is significant only at the 10 percent level, indicating that different banks achieved the desired increase in excess liquidity by adjusting on different margins. Consequently, the tiering system was not associated with significant changes in banks' capital structure and wholesale borrowing, mitigating concerns about financial stability.

Importantly, we observe no changes in net borrowing in the secured market for banks with more unused allowances during the interim period. Columns (4)-(6) show that similar developments took place in the unsecured market, albeit at somewhat smaller magnitude, in line with the descriptive evidence in Fig. 3.

The effects we document are economically meaningful. As outlined in Section 3, each eligible bank received a tiering allowance exempting excess liquidity holdings up to six times their MRR from the application of the negative DFR. The average treatment effect of between 0.7–1.7 times banks' MRR thus implies that banks with a one percentage point higher unused exemptions increased their net borrowing in the money market by around one-sixth of their total allowance more than banks without unused allowances. The average treatment effect is also substantial relative to the stock of outstanding money market transactions during the sample period, which amounts to around 2.2 times MRR in the secured segment and around 7.3 times MRR in the unsecured

[7] Since the global financial crisis, trading in the euro area had shifted from the unsecured to the secured money market segment reflecting the greater regulatory costs of unsecured transactions as well as a stronger sensitivity to counterparty risk.

[8] Banks with unused allowances, on average, more than quadrupled their net borrowing in the secured segment from EUR 1 billion (bn) to EUR 4.5bn between October and November 2019. In aggregate terms, this amounted to additional net borrowing of EUR 44.8bn by this group of banks. In contrast, banks without unused exemptions increased their net lending in the secured money market from EUR 2.4bn to EUR 4.2bn on average, or by EUR 56.9bn in aggregate terms. In the unsecured market, banks with unused allowances increased their net exposure from EUR 9.2bn to EUR 9.6bn on average from October to November, or by around EUR 5.6bn in the aggregate; banks without unused exemptions reduced their net borrowing marginally from EUR 9.5bn to EUR 9.2bn, or around EUR 11bn in the aggregate.

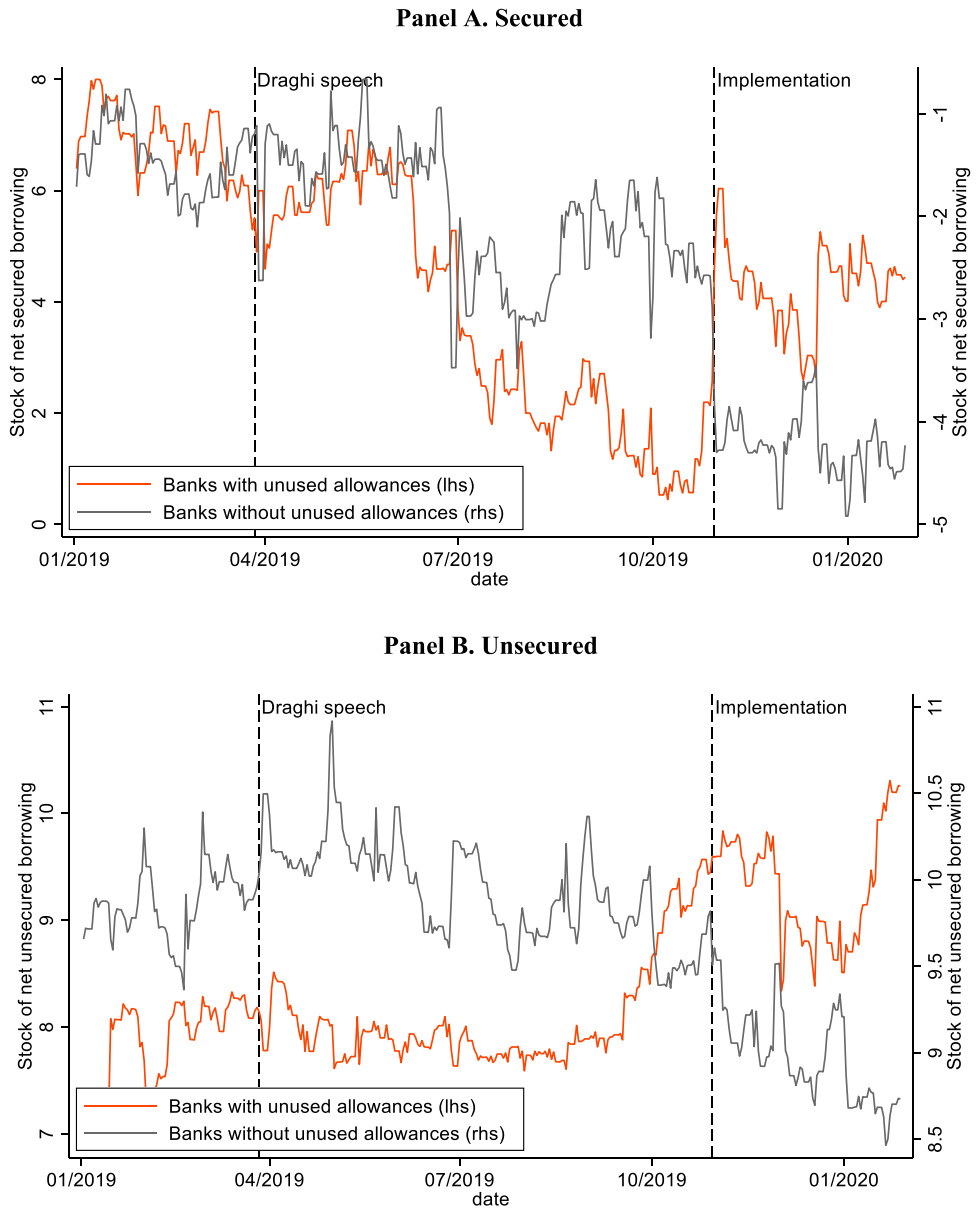

Fig. 3. Net borrowing in the money market
The figure shows the average outstanding stock of net borrowing by banks in EUR billion. The stock of net borrowing is defined as the volume of outstanding borrowing transactions at the end of the day minus the volume of outstanding lending transactions. Panel A is based on transactions in the secured money market segment, and Panel B is based on transactions in the unsecured segment. The data is split between banks with unused tiering allowances (red line, left-hand side axis) and without (grey line, right-hand side axis) during the maintenance period immediately preceding the start of the tiering system at the end of October 2019. Vertical lines mark the speech by President Draghi on March 27, 2019, which first referred to the possibility of introducing a tiering system, as well as to the eventual start of the system on October 30, 2019.

segment (see Table 1, panel C).

Panel B suggests that the additional borrowing by banks with unused exemptions was met by an elastic supply of liquidity because it carried neither systematically higher interest rates (columns 1 and 2), nor did it lead to meaningful maturity rationing (columns 3 and 4). These findings hold both in the secured and in the unsecured segment of the money market.

Overall, these results suggest that following the tiering implementation, the willingness and ability to borrow reserves increased for banks with unused exemptions, due to their ability to store liquidity at a non-negative rate. The results also support our framework assumption that banks with high reserve holdings had reached a satiation point and, therefore, did not require a higher interest rate to transfer reserves through the money market.

To sharpen the identification of the demand for reserves, we construct a relationship level daily dataset of money market transactions and focus on the unsecured market, because the prevalence of transactions with central counterparties in the secured market limits our ability to observe bilateral flows. In this context, we can use high-dimensional fixed effects to control for shocks that may have affected the supply of credit of banks' counterparties (Khwaja and Mian, 2008).

Panel C controls for the supply of short-term funding by including interactions of lender (counterparty) and maintenance period fixed effects. The results show that unsecured borrowing from the same counterparty rose significantly more for banks with more unused exemptions than for banks without unused exemptions. This finding is robust if we control for characteristics of the relationships by including the interaction between borrowing bank and lending counterparty fixed effects or

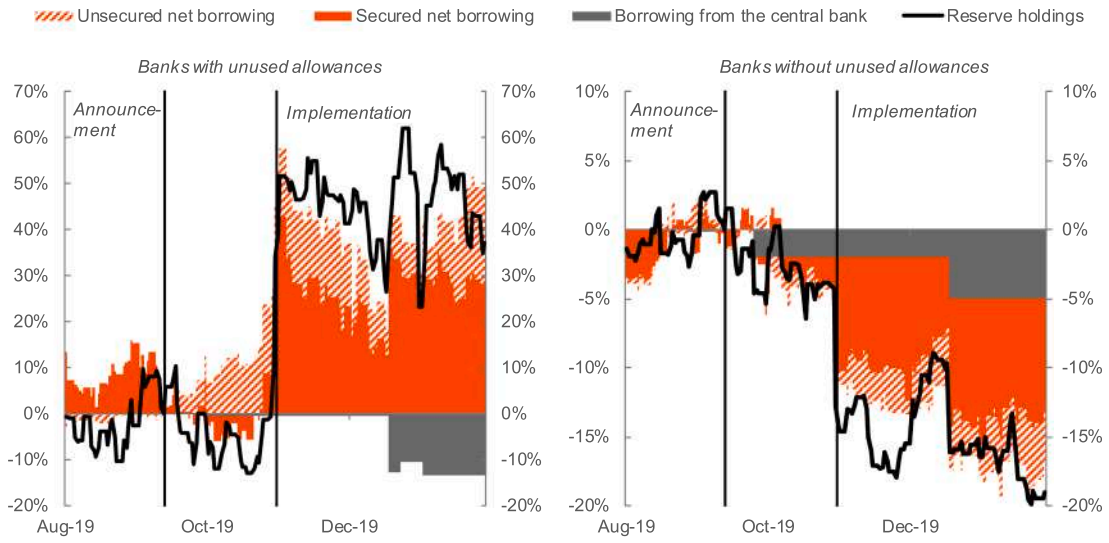

Fig. 4. Change in reserve holdings, money market net borrowing, and central bank borrowing
The figure shows the change in reserve holdings, net borrowing in the money market, and borrowing from the central bank by banks with (left panel) and without (right panel) unused allowances as of October 2019, right before the tiering implementation. The relevant cut-off date for determining the minimum reserve requirements (and therefore the tiering allowance) for the maintenance period ending on October 2019 were July 2019 (for banks reporting monthly) or June 2019 (for banks reporting quarterly). All series are normalized to banks' reserve holdings on September 12, 2019, the date at which the introduction of the two-tier system was formally announced (first vertical dashed line). The second vertical line indicates the start of the tiering system implementation (October 30, 2019). The residual change in reserve holdings can be attributed to other sources of banks' liquidity management, such as the purchase or sale of securities.

shocks to the country of the borrowers that may drive the demand for liquidity. In line with the results in Panel B, the additional borrowing volumes did not require a significantly higher borrowing rate, as shown in column (4), further supporting the conclusion that the supply of liquidity was elastic for banks with unused exemptions.

We also explore which counterparties provided more liquidity to banks with unused exemptions for the subset of transactions in the bank-to-bank market. To do so, we include in the specification in column 3 of Panel C, a triple interaction term between Implementation_t, a bank's exposure to the tiering system, $\text{Exposure}_i^{Oct\ 2019}$, and the counterparty's excess liquidity holdings above its allowance relative to its total assets during the maintenance period before the implementation of the tiering.[9] Fig. 6 shows how the net borrowing of a bank with positive average unused exemptions varied with the counterparty's excess liquidity. The increasing slope of the coefficient implies that banks with unused allowances borrowed more from banks with higher excess liquidity. This finding supports the interpretation that liquidity flowed from high excess liquidity banks to banks with high unused exemptions and led to a more even distribution of reserves.

Table IA.2 further considers bank balance sheet data to evaluate how the tiering affected other bank liabilities and the size of their balance sheets. We observe no changes in deposits for banks with higher unused exemptions, further indicating that the reallocation of liquidity occurred largely through the money market. Together with the evidence that the size of banks with higher unused exemptions did not change after the implementation of the tiering, this suggests that an increase in excess liquidity holdings was not accompanied by a more fragile capital structure.

5.3. Bond holdings and bank lending

Our conceptual framework implies that banks that can more efficiently insure against liquidity shocks with higher reserve holdings have incentives to rebalance away from securities, such as government bonds. By doing so, they can also generate liquidity, complementing their money market borrowing. We, therefore, apply the empirical framework outlined above to explore our empirical prediction on banks' government securities holdings.

Table 4, Panel A shows that consistent with our simple framework, banks with unused allowances decreased their holdings of government securities relative to their assets after the tiering implementation. A one-standard-deviation increase in a bank's *ex ante* unused allowances is associated with a decrease in the holdings of government securities by close to 4 bps of total assets (corresponding to just under 10 % of the standard deviation of this variable).

Our framework also implies that facing higher interest rates, low excess liquidity banks had limited ability to insure against liquidity risks through the money market. We ask whether synergies on banks' balance sheets are such that this constrained lending by considering banks' outstanding loans. In Panel B, we do not observe an increase in the amount of credit outstanding for banks with unused exemptions after the implementation of the tiering. However, using bank level data, we cannot control for potential changes to credit demand. This is particularly important in our context because the tiering was adopted when all banks, and banks with unused exemptions to an even larger extent, were facing a decrease in credit demand. This is evident from Figure IA.2, which, using data from the ECB's Bank Lending Survey, shows that the share of banks reporting increasing loan demand was decreasing and even more so for banks with unused exemptions. This finding is consistent with the evidence in Panel B that the outstanding credit of banks with unused exemptions was decreasing during the interim period.

Yet, an increase in excess liquidity by banks with unused exemptions could have led to a rightward shift in their supply of bank loans, holding constant the quality of potential borrowers and the demand for credit (see e.g., Bernanke and Lown, 1991, for such a definition). Since based on Figure IA.2, the borrowers of banks with low excess liquidity are likely to have experienced stronger contemporaneous negative demand shocks than the clients of other banks, we are unable to identify whether the tiering sustained the supply of credit using bank balance sheet data. For this reason, in the next section, we revisit this question considering

[9] This restricts the sample to the interbank market, i.e., to transactions in which both the borrowing and lending counterparties can hold central bank reserves.

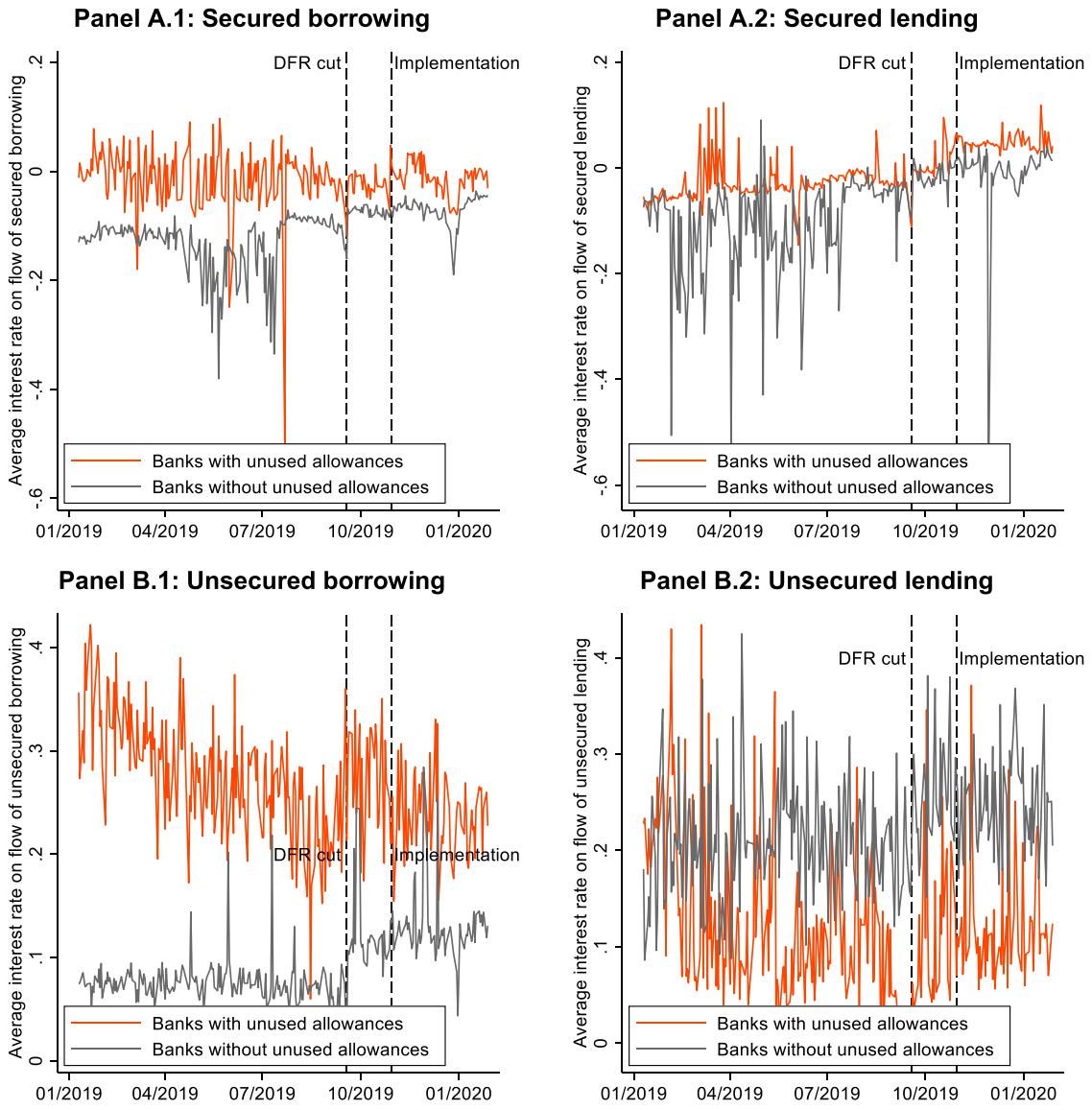

Fig. 5. Money market interest rates
The figure shows the volume-weighted average interest rates on the flow of new money market transactions by reporting banks per day, expressed as a spread over the prevailing DFR. The average is computed across all reporting banks and maturities. The red line indicates the values for banks with unused allowances, and the grey line banks without unused allowances under the tiering system. The vertical lines indicate the date when the reduction of the DFR took effect (September 18, 2019) and the start of the tiering system implementation (October 30, 2019).

banks' outstanding credit to different borrowers and controlling non-parametrically for credit demand.

6. The effects of the tiering system on loan supply

6.1. Methodology and main results

Our objective is to explore whether the increase in excess liquidity holdings by banks with *ex ante* low reserves fosters bank lending. To achieve this and to control for the demand for credit of the customers of different banks, we use Anacredit, which allows us to observe a bank's exposure to each single borrower and control for borrower heterogeneity.

As in our earlier tests, we exploit banks' exposure to the tiering system through unused exemptions to test whether a reallocation of reserves towards banks with higher liquidity needs increases credit supply. Specifically, we estimate the following equation:

$$\begin{aligned} Loan_{f,i,t} = {} & \beta_1 \left(\text{Interim}_t \times \text{Exposure}_i^{Feb\ 2019}\right) \\ & + \beta_2 \left(\text{Implementation}_t \times \text{Exposure}_i^{Oct\ 2019}\right) + \beta_3 X_{i,t} + \gamma_{f,t} + \delta_{i,f} \\ & + \varepsilon_{f,i,t}, \end{aligned} \tag{4}$$

where the dependent variable is the outstanding credit of bank i to firm f during month t. In determining the credit exposure of bank i to firm f, we aggregate all outstanding credit facilities that bank i has extended to firm f as of time t, including drawn credit lines.[10] The indicator variables $Interim_t$ and $Implementation_t$ capture the different phases of the process that led to the introduction of the tiering. As in our earlier tests, the

[10] If anything, our results are stronger if we exclude drawn credit lines, which we include to be in line with standard statistics on the volume of credit. Borrowers started to abnormally draw down credit lines only after the end of our sample period, when the Covid pandemic erupted.

Table 3
Money market volumes around the tiering introduction.

Panel A. Bank-level regressions
The table shows results from difference-in-differences regressions of banks' money market activities on the exposure to the tiering system. The dependent variable in all columns is the banks' stock of borrowing, lending, or net borrowing, scaled by their minimum reserve requirements. "Exposure (Feb 2019)" is equal to the maximum of the unused exemption allowance (as a percentage of total assets) of bank *i* and zero between January 30 and March 12, 2019, the last maintenance period before the speech by former ECB President Draghi on March 27, 2019, in which he hinted at the introduction of a tiering system for the first time. "Exposure (Oct 2019)" is defined in the same way, but for the period between September 18 and October 29, 2019, the last maintenance period before the actual implementation of the tiering system. The "Interim (Mar-Oct 2019)" variable is an indicator for the time between the Draghi's speech and the eventual implementation of the system as of October 30, 2019. "Implementation (Nov 2019-Feb 2020)" is an indicator variable for the time between October 30, 2019 and January 28, 2020, i.e., the maintenance periods in which the tiering system was implemented but before the pandemic accelerated in early 2020. "CDS" represents banks' CDS spread (in percentage points); for state-owned banks in the sample, this is measured as the domestic sovereign CDS spread. All regressions include bank fixed effects as well as country-maintenance period fixed effects. The observation frequency in all regressions is daily, and the sample period ranges from January 1, 2017 to January 28, 2020. Robust standard errors (reported in parentheses) are clustered at the bank and maintenance period level. ***, **, and * denote statistical significance at the 1 %, 5 %, and 10 % level, respectively.

	Secured			Unsecured		
	Borrowing (1)	Lending (2)	Net (3)	Borrowing (4)	Lending (5)	Net (6)
Exposure (Feb 2019) x Interim (Mar-Oct 2019)	−0.195	−0.635	0.440	−0.030	−0.039	0.009
	(0.466)	(0.394)	(0.498)	(0.207)	(0.053)	(0.202)
Exposure (Oct 2019) x Implementation (Nov 2019-Feb 2020)	0.588	−1.136*	1.724**	0.551*	−0.135	0.687**
	(0.429)	(0.583)	(0.658)	(0.321)	(0.100)	(0.272)
CDS	−0.766	−0.412	−0.354	1.707	0.067	1.641
	(0.592)	(0.672)	(0.996)	(1.765)	(0.090)	(1.696)
Country-MP fixed effects	Y	Y	Y	Y	Y	Y
Bank fixed effects	Y	Y	Y	Y	Y	Y
Observations	44,269	44,269	44,269	44,269	44,269	44,269
No. Banks	42	42	42	42	42	42
R2	0.920	0.910	0.878	0.802	0.939	0.837
R2 (within)	0.002	0.002	0.004	0.006	0.001	0.005

Panel B. Bank-level regressions on money market borrowing' contractual features
The table shows results from difference-in-differences regressions of banks' money market activities on the exposure to the tiering system. The dependent variable in columns (1) and (2) is the volume-weighted average interest rate on banks' borrowing in the secured and unsecured money market, respectively, expressed as a spread over the prevailing DFR. In columns (3) and (4), the dependent variable is the volume-weighted average maturity of the outstanding borrowing in the secured and unsecured segment, respectively. All other variables are defined as explained in notes to Panel A. All regressions include bank fixed effects as well as country-maintenance period fixed effects. The observation frequency in all regressions is daily, and the sample period ranges from January 1, 2017 to January 28, 2020. Robust standard errors (reported in parentheses) are clustered at the bank and maintenance period level. ***, **, and * denote statistical significance at the 1 %, 5 %, and 10 % level, respectively.

	Borrowing rate		Borrowing maturity	
	Secured (1)	Unsecured (2)	Secured (3)	Unsecured (4)
Exposure (Feb 2019) x Interim (Mar-Oct 2019)	−0.006	0.014	3.981	−2.787
	(0.007)	(0.023)	(2.670)	(3.803)
Exposure (Oct 2019) x Implementation (Nov 2019-Feb 2020)	0.001	0.042	1.885	−4.815
	(0.012)	(0.027)	(1.759)	(5.380)
CDS	0.032	0.004	8.685	−0.574
	(0.020)	(0.018)	(6.213)	(4.218)
Country-MP fixed effects	Y	Y	Y	Y
Bank fixed effects	Y	Y	Y	Y
Observations	42,527	44,016	42,527	44,016
No. Banks	42	42	42	42
R2	0.696	0.938	0.767	0.714
R2 (within)	0.003	0.010	0.025	0.002

Panel C. Relationship-level regressions
The table shows results from difference-in-differences regressions of banks' unsecured net borrowing on exposure to the tiering system at the bank-counterparty level. The dependent variable in columns (1)-(3) is the banks' stock of outstanding net borrowing per counterparty, and in column (4) the volume-weighted borrowing rate on the outstanding stock of borrowing per counterparty. Variables are defined as explained in notes to Panel A. Column (1) includes bank fixed effects as well as bank's country-maintenance period fixed effects. Column (2) includes bank fixed effects and counterparty-maintenance period fixed effects. Column (3) contains bank-counterparty fixed effects, counterparty-maintenance period fixed effects, and lender's country-maintenance period fixed effects. The observation frequency in all regressions is daily, and the sample period ranges from January 1, 2017 to January 28, 2020. Robust standard errors (reported in parentheses) are clustered at the bank and maintenance period level. ***, **, and * denote statistical significance at the 1 %, 5 %, and 10 % level, respectively.

Dependent variable:	Unsecured net borrowing volumes			Unsecured borrowing rate
	(1)	(2)	(3)	(4)
Exposure (Feb 2019) x Interim (Mar-Oct 2019)	−0.002*	0.0199*	0.012	−0.003
	(0.001)	(0.011)	(0.009)	(0.004)
Exposure (Oct 2019) x Implementation (Nov 2019-Feb 2020)	0.002*	0.016*	0.009***	−0.005
	(0.001)	(0.008)	(0.003)	(0.003)
CDS	0.007	0.009	0.018	0.002
	(0.006)	(0.011)	(0.016)	(0.004)
Bank's country-MP fixed effects	Y	–	Y	Y
Bank fixed effects	Y	Y	–	–
Counterparty-MP fixed effects	–	Y	Y	Y
Bank-counterparty fixed effects	–	–	Y	Y
Observations	23,337,146	23,333,780	23,333,780	2,450,325

(*continued on next page*)

Table 3 (*continued*)

Panel C. Relationship-level regressions

The table shows results from difference-in-differences regressions of banks' unsecured net borrowing on exposure to the tiering system at the bank-counterparty level. The dependent variable in columns (1)-(3) is the banks' stock of outstanding net borrowing per counterparty, and in column (4) the volume-weighted borrowing rate on the outstanding stock of borrowing per counterparty. Variables are defined as explained in notes to Panel A. Column (1) includes bank fixed effects as well as bank's country-maintenance period fixed effects. Column (2) includes bank fixed effects and counterparty-maintenance period fixed effects. Column (3) contains bank-counterparty fixed effects, counterparty-maintenance period fixed effects, and lender's country-maintenance period fixed effects. The observation frequency in all regressions is daily, and the sample period ranges from January 1, 2017 to January 28, 2020. Robust standard errors (reported in parentheses) are clustered at the bank and maintenance period level. ***, **, and * denote statistical significance at the 1 %, 5 %, and 10 % level, respectively.

Dependent variable:	Unsecured net borrowing volumes			Unsecured borrowing rate
	(1)	(2)	(3)	(4)
No. Banks	42	42	42	42
R2	0.021	0.231	0.761	0.976
R2 (within)	0.001	0.001	0.001	0.001

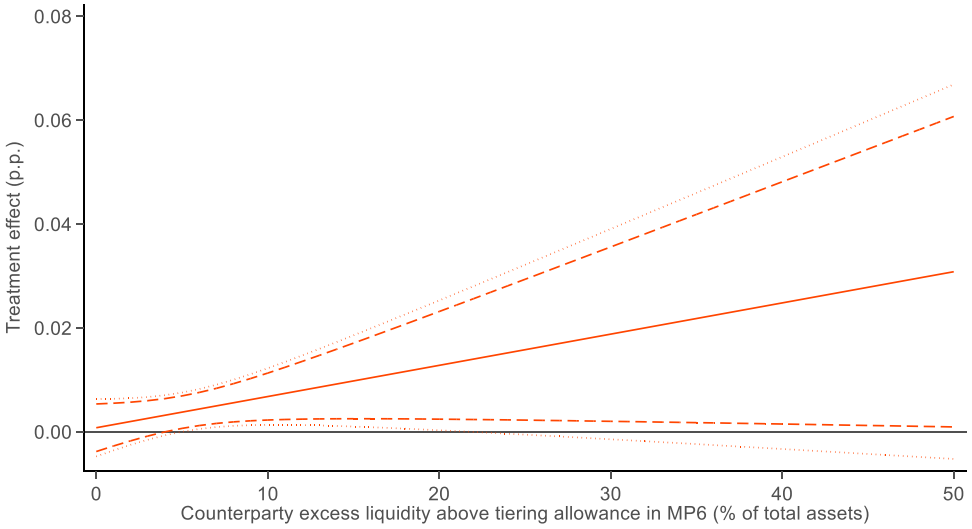

Fig. 6. Increase in net unsecured borrowing conditional on unused allowances and counterparty' excess liquidity

The figure shows the effect of the two-tier system on banks' bilateral net borrowing in the unsecured market, conditional on the borrowing bank having unused allowances equal to the sample average, and conditional on the counterparty having liquidity holdings in excess of its tiering allowance as indicated on the horizontal axis. Specifically, the chart plots the change in net borrowing of a bank with average unused exemptions above zero after the implementation of the tiering as a function of the excess liquidity of the counterparty (above the tiering allowance and in percent of total assets): $\beta_2 \mathbf{Exposure}^{Oct\ 2019} + \beta_4 \mathbf{Exposure}^{Oct\ 2019} \times \mathbf{Counterparty\ Excess\ Liquidity}_{jt}$. We vary the counterparty's excess tiering allowances ranging from 0 % to 50 % of total assets. Dashed lines indicate the 90 % confidence interval, dotted lines the 95 % confidence interval.

exposure variables are defined as the unused exemptions in the maintenance periods just before the first mentioning of tiering in then-President Draghi's speech and before the tiering implementation, respectively, and are expressed in percentage of a bank's assets. Specifically, the October 2019 exposure variable captures an increase in excess liquidity driven by the unused exemptions because the unused exemptions were nearly entirely filled after the implementation of the tiering system. The February 2019 exposure variable captures any adjustments occurring in the interim period, which, as shown by the evidence on the money market, were limited because no banks were yet to experience an increase in the marginal return of reserves.

The matrix $X_{i,t}$ consists of bank level controls including the bank's CDS spread, (contemporaneous) excess liquidity, holdings of government bonds, deposit ratio, and use of TLTRO funds. In the most stringent specifications, we include interactions of bank and firm fixed effects, capturing time-invariant aspects of the relationships.

The granularity of Anacredit allows us to control for loan demand and identify the supply of credit by including either interactions of firm and time fixed effects (Khwaja and Mian, 2008) or interactions of industry, location, size decile, and time fixed effects (Acharya et al., 2019; Degryse et al., 2019). In practice, we test the extent to which banks with different exposures to the tiering supply credit to the same borrower or to borrowers that are expected to experience similar demand shocks because they are in the same cluster defined by their city, industry, and size group.

The estimates in Panel A of Table 5 show that banks with unused exemptions extended more credit than other banks after the implementation of the tiering system. The estimated effects are qualitatively similar when we absorb shocks to the demand for credit using interactions of country and time effects in column (1), interactions of industry, location, size decile, and time fixed effects in column (2), interactions of firm and time fixed effects in column (3), and when we add interactions of bank and firm fixed effects in column (4). A one-percentage-point increase in exemption allowances (which is close to a one standard deviation of this variable) corresponds to an increase in credit to a given firm by 4–7 %, depending on the fixed effects included.

Importantly, we find that differences in lending before the implementation period are limited as the interaction between the *Interim* dummy and the *Exposure* proxy is not statistically significant across different specifications. This indicates that the actual reallocation of liquidity is an important driver of the cross-sectional differences in bank lending and that our estimates are unlikely to capture pre-existing trends.

Fig. 7 provides further evidence to address concerns that pre-existing

Table 4
Changes in bank asset composition.

Panel A. Government bond holdings

The table shows results from difference-in-differences regressions of banks' government bond holdings on exposure to the tiering system. The dependent variable in all columns is the bank's monthly change in the ratio of government bonds over assets. "Exposure(Feb 2019)" is equal to the unused exemption allowance (as a percentage of main assets) of bank *i* in February 2019 if such difference is positive, and to zero otherwise. "Exposure(Oct 2019)" is defined in the same way, but as of October 2019. The "Interim (Mar-Oct 2019)" variable is an indicator for the time between the speech by former ECB President Draghi on March 27, 2019, in which he hinted at the introduction of a tiering system for the first time, and the eventual implementation of the system as of October 30, 2019. "Implementation (Nov 2019-Feb 2020)" is an indicator variable for the time after October 30, 2019, i.e., the time when the tiering system took effect. "CDS" represents banks' CDS spread (in percentage points); for state-owned banks in the sample, this is measured as the domestic sovereign CDS spread. The observation frequency in all regressions is monthly, and the sample period ranges from January 2014 to February 2020. Standard errors are clustered at the bank and country-time level. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1 %, 5 %, and 10 % level, respectively.

Dependent Variable: Monthly change in holdings of government securities	(1)	(2)	(3)
Exposure(Feb 2019)	0.006		
	(0.005)		
Exposure(Feb 2019)*Interim(Mar-Oct 2019)	−0.021	−0.020	−0.021
	(0.012)	(0.013)	(0.013)
Exposure(Oct 2019)	−0.000		
	(0.005)		
Exposure(Oct 2019)*Implementation(Nov 2019-Feb 2020)	−0.026**	−0.026**	−0.026**
	(0.012)	(0.012)	(0.012)
CDS			−0.016
			(0.012)
Country-month FE	Yes	Yes	Yes
Bank FE	–	Yes	Yes
Observations	9,325	9,325	9,325
R-squared	0.208	0.217	0.217

Panel B. Loan volumes

The table shows how bank loan volumes to firms changed after the announcement and implementation of the tiering depending on the banks' exposure to the tiering system. The dependent variable in all columns is the bank's monthly change in the ratio of the stock of outstanding loans to all non-financial corporations over assets. "Exposure(Feb 2019)" is equal to the unused exemption allowance (as a percentage of main assets) of bank *i* in February 2019 if such difference is positive, and to zero otherwise. "Exposure (Oct 2019)" is defined in the same way, but as of October 2019. The "Interim (Mar-Oct 2019)" variable is an indicator for the time between the speech by former ECB President Draghi on March 27, 2019, in which he hinted at the introduction of a tiering system for the first time, and the eventual implementation of the system as of October 30, 2019. "Implementation (Nov 2019-Feb 2020)" is an indicator variable for the time after October 30, 2019, i.e., the time when the tiering system took effect. "CDS" represents banks' CDS spread (in percentage points); for state-owned banks in the sample, this is measured as the domestic sovereign CDS spread. The observation frequency in all regressions is monthly, and the sample period ranges from January 2014 to February 2020. Standard errors are clustered at the bank and country-time level. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1 %, 5 %, and 10 % level, respectively.

Dependent Variable: Monthly change in NFC loans	(1)	(2)	(3)
Exposure(Feb 2019)	0.017*		
	(0.009)		
Exposure(Feb 2019)*Interim(Mar-Oct 2019)	−0.052**	−0.052**	−0.052**
	(0.022)	(0.023)	(0.023)
Exposure(Oct 2019)	−0.008		
	(0.007)		
Exposure(Oct 2019)*Implementation(Nov 2019-Feb 2020)	0.015	0.015	0.015
	(0.047)	(0.048)	(0.048)
CDS			0.000
			(0.012)
Country-month FE	Yes	Yes	Yes
Bank FE	–	Yes	Yes
Observations	9,325	9,325	9,325
R-squared	0.173	0.182	0.182

differences in lending of banks with unused exemptions may be driving our findings. We plot how the coefficient on $\text{Exposure}_i^{Oct\ 2019}$ varies over our sample period. The coefficient is positive and statistically significant only in the months following the implementation of the tiering system, confirming the importance of the actual reallocation of liquidity.

Our dependent variable in Panel A is the exposure of a bank to a given borrower during a month. Thus, its changes capture both new loans and the size of new loans, reflecting both the extensive and the intensive margin of bank lending as far as existing borrowers are concerned. Panel B of Table 5 focuses on the extensive margin of bank lending, considering new relationships (columns 1 to 4), defined as new loans to borrowers to which the bank did not have a preexisting exposure, and terminated relationships (columns 5 to 8), defined as relationships with firms with which a bank stops having a positive exposure. It appears that banks which after October 2019 increased their liquidity holdings as a result of the tiering are more likely to grant loans to new borrowers. A one-standard-deviation increase in exposure to the tiering in October 2019 results in a 3 % increase in the probability that the bank establishes a new relationship, corresponding to more than a third of the unconditional probability of a new relationship (equal to 8.7 %). In columns 5 to 8, we observe no difference in propensity to terminate relationships with existing borrowers between banks. This suggests that banks that transferred their excess liquidity holdings did not cut the supply of credit.

Overall, Table 5 supports our hypothesis that banks with unused exemptions increased the supply of credit thanks to the insurance provided by their higher excess liquidity holdings. Table 6 considers whether the tiering introduction may have affected bank lending through alternative mechanisms. Specifically, the tiering was introduced to alleviate the effects of negative rates on banks' profitability. In the aggregate, according to the ECB's estimates, the tiering system introduced savings equivalent to 20 basis points of banks' ROE, an effect that is probably quantitatively too small to affect bank lending (Boucinha et al. 2022). Nevertheless, to evaluate whether this is the case, we consider banks' tiering savings. If high-unused-exemption banks had simply benefitted from a higher return on their assets, we should observe that banks that had enough liquidity to fill their exemptions in October 2019 also benefited from higher returns on their reserves and extended more loans. In order test the relevance of this effect, we compute the Tiering Benefits(Oct 2019) as $[\min\{0, DFR \times (ExcessLiquidity - MRR \times 6)\} - DFR \times ExcessLiquidity]/Assets$ upon the introduction of the tiering system and before the redistribution of reserves.

Column 1 shows that the coefficient on Tiering Benefits(Oct 2019) *Implementation(Nov 2019-Feb 2020) is statistically insignificant, casting doubt on the relevance of the profit channel.[11]

This finding also indicates that the lending policies of banks with *ex ante* high excess reserves, which transferred their excess liquidity to other banks, are unaffected by a drop in reserves. Similarly, in column 2, we find no differences in lending between banks with different *ex ante* levels of excess liquidity. Also in this case, we do not find that banks with high excess liquidity lent less after the introduction of the tiering, supporting our conjecture that banks with high excess liquidity holdings had reached their satiation point for reserves and consequently do not lend less when they transfer their reserves to banks with unused exemptions.

In Table 7, we consider that the tiering system was announced in September 2019 at the same time as several other policy changes. Specifically, the interest rate on the deposit facility was decreased by 10

[11] In Table IA.3, we also consider banks that had a more favorable price reaction in March 2019, when the possibility of the tiering was first hinted at. We use the price reaction as a proxy for the profit/net wealth channel. The interaction between the price reaction, which captures the positive wealth effect due to the tiering, and the implementation dummy is not statistically significant.

Table 5
The effects of unused exemptions on bank lending.

Panel A. Outstanding loan volumes
The table shows how banks' lending to firms changes after the announcement and implementation of the tiering depending on the banks' exposure to the tiering system. The dependent variable is the logarithm of loans by bank *i* to a non-financial corporation *f* in month *t*. "Exposure(Feb 2019)" is equal to the unused exemption allowance (as a percentage of main assets) of bank *i* in February 2019 if such difference is positive, and to zero otherwise. "Exposure(Oct 2019)" is defined in the same way, but as of October 2019. The "Interim (Mar-Oct 2019)" variable is an indicator for the time between the speech by former ECB President Draghi on March 27, 2019, in which he hinted at the introduction of a tiering system for the first time, and the eventual implementation of the system as of October 30, 2019. "Implementation (Nov 2019-Feb 2020)" is an indicator variable for the time after October 30, 2019, i.e., the time when the tiering system took effect. Control variables are as defined in Table 1, Panel B. The observation frequency in all regressions is monthly, and the sample period ranges from September 2018 to February 2020. Standard errors are clustered at the bank-time-period level. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1 %, 5 %, and 10 % level, respectively.

Dependent Variable:	(1)	(2)	(3)	(4)
Volume of NFC loans	Log	Log	Log	Log
Exposure(Feb 2019)*Interim(Mar-Oct 2019)	0.012	0.007	0.013	0.011
	(0.011)	(0.006)	(0.010)	(0.009)
Exposure(Oct 2019)*Implementation(Nov 2019-Feb 2020)	0.066***	0.040***	0.074***	0.066***
	(0.025)	(0.012)	(0.017)	(0.019)
CDS	−0.049	−0.021	−0.034	−0.045
	(0.040)	(0.020)	(0.032)	(0.033)
Excess liquidity	0.010**	0.002	0.009**	0.006
	(0.005)	(0.002)	(0.005)	(0.004)
Holdings of government securities	0.055***	0.026***	0.047***	0.038**
	(0.016)	(0.009)	(0.016)	(0.016)
Deposit ratio	0.000	−0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
TLTRO funds	0.005*	0.002*	0.004**	0.003**
	(0.002)	(0.001)	(0.002)	(0.001)
Bank FE	Yes	Yes	Yes	–
Country-Month FE	Yes	-	-	-
Industry-Location-Size-Month FE	–	Yes	–	–
Firm-Month FE	–	–	Yes	Yes
Bank-Firm FE	–	–	–	Yes
Observations	35,356,355	34,338,371	10,353,666	10,256,326
R-squared	0.084	0.719	0.697	0.935

Panel B. New and terminated lending relationships
The table shows how banks' lending relationships with firms change after the announcement and implementation of the tiering depending on the banks' exposure to the tiering system. In columns (1) to (4), the dependent variable is a dummy that takes the value of 1 if a relation between bank *i* and firm *f* in month *t* exists (i.e., the volume of outstanding loans is a strictly positive) but it did not exist in month *t-1*, 0 otherwise. For columns (5) to (8), the dependent variable is a dummy that takes value 1 if a relation between bank *i* and firm *f* in month *t* does not exist but it existed in month *t-1*, 0 otherwise. "Exposure(Feb 2019)" is equal to the unused exemption allowance (as a percentage of main assets) of bank *i* in February 2019 if such difference is positive, and to zero otherwise. "Exposure(Oct 2019)" is defined in the same way, but as of October 2019. The "Interim (Mar-Oct 2019)" variable is an indicator for the time between the speech by former ECB President Draghi on March 27, 2019, in which he hinted at the introduction of a tiering system for the first time, and the eventual implementation of the system as of October 30, 2019. "Implementation (Nov 2019-Feb 2020)" is an indicator variable for the time after October 30, 2019, i.e., the time when the tiering system took effect. Control variables are as defined in Table 1Table 1, Panel B. The observation frequency in all regressions is monthly, and the sample period ranges from September 2018 to February 2020. Standard errors are clustered at the bank-time-period level. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1 %, 5 %, and 10 % level, respectively.

Dependent Variable:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dummy(New Relationship)				Dummy(Terminated Relationship)			
	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Exposure(Feb 2019)*Interim(Mar-Oct 2019)	0.011	0.012	0.016	0.016*	−0.000	−0.000	−0.001	−0.001
	(0.009)	(0.009)	(0.010)	(0.010)	(0.001)	(0.001)	(0.001)	(0.001)
Exposure(Oct 2019)*Implementation(Nov 2019-Feb 2020)	0.027**	0.031**	0.035**	0.035**	0.003	0.001	−0.001	−0.001
	(0.012)	(0.014)	(0.017)	(0.017)	(0.003)	(0.001)	(0.002)	(0.002)
CDS	0.052*	0.065*	0.054*	0.054*	0.005	0.003	0.001	0.001
	(0.029)	(0.034)	(0.031)	(0.032)	(0.005)	(0.002)	(0.003)	(0.003)
Excess liquidity	−0.006	−0.007	−0.007	−0.008	0.002*	−0.000	0.001	0.001
	(0.005)	(0.006)	(0.009)	(0.009)	(0.001)	(0.000)	(0.001)	(0.001)
Holdings of government securities	−0.016	−0.016	−0.014	−0.015	−0.001	−0.001*	−0.000	−0.000
	(0.010)	(0.012)	(0.013)	(0.014)	(0.002)	(0.001)	(0.001)	(0.001)
Deposit ratio	0.001	0.001	0.001	0.001	−0.000***	−0.000***	−0.000***	−0.000***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
TLTRO funds	−0.005	−0.004	−0.003	−0.003	0.000	0.000	0.000	0.000
	(0.007)	(0.008)	(0.010)	(0.010)	(0.001)	(0.000)	(0.000)	(0.000)
Bank FE	Yes	Yes	Yes	–	Yes	Yes	Yes	–
Country-Month FE	Yes	-	-	-	Yes	-	-	-
Industry-Location-Size-Month FE	–	Yes	–	–	–	Yes	–	–
Firm-Month FE	–	–	Yes	Yes	–	–	Yes	Yes
Bank-Firm FE	–	–	–	Yes	–	–	–	Yes
Observations	52,814,649	41,330,058	17,903,543	17,903,543	52,814,649	41,330,058	17,903,543	17,903,543
R-squared	0.254	0.362	0.516	0.565	0.034	0.177	0.432	0.481

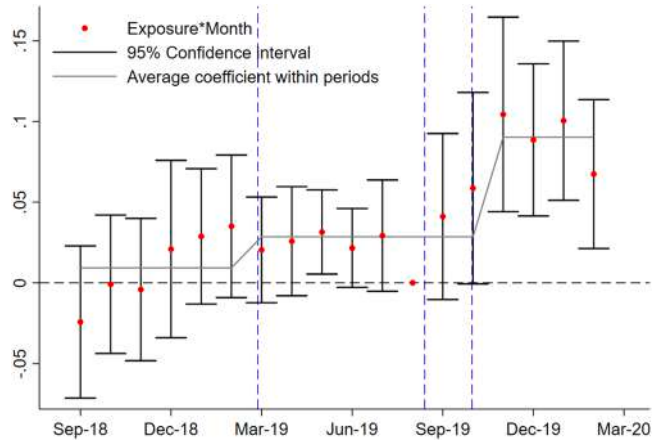

Fig. 7. Dynamic effects of unused exemptions on bank loan supply
In order to test whether our results may be driven by pre-existing trends, we estimate a specification analogous to that in column 3 of Table 7, in which instead of including the terms Exposure(Feb 2019)*Interim(Mar-Oct 2019) and Exposure(Oct 2019)*Implementation (Nov 2019-Feb 2020), we interact Exposure(Oct 2019) with time dummies. The figure reports the estimated coefficients on each of these interactions and the 95 % confidence interval.

basis points to −0.50 % and the widely expected continuation of the APP as well as an easing of the TLTRO conditions were announced. A potential concern for our identification strategy would be that banks with unused exemptions were more exposed to these policy changes. We therefore control for the exposures to these policies by including in our specifications a bank's excess liquidity and deposit ratio, which account for the exposure to the interest rate cut below the zero lower bound (Bottero et al. 2022; Heider et al., 2019); the holdings of government bonds, which account for a bank's direct exposure to the security price appreciation driven by the APP (Acharya et al., 2019), and the use of TLTRO funds. In addition, we show that our results are robust to the inclusion of interactions of bank and time fixed effects. Furthermore, in Table 7, our results are qualitatively and quantitatively invariant if we interact all bank level controls with the post implementation dummy. This is the case even if we consider interactions with bank size and capital in columns (5) and (6).

Taken together, these results suggest that banks with unused exemptions were more willing to extend credit after increasing their reserve holdings, while the lending behavior of banks with *ex ante* higher excess liquidity holdings was unaffected. Such an interpretation is also consistent with the finding that the supply of credit by banks with high unused allowances increased only after October 2019, when the money markets started to reallocate liquidity.

6.2. Additional evidence on the mechanism

Table 8 provides more direct evidence on our conjecture that the redistribution of reserves was the driving force behind the increase in credit supply. Our conceptual framework implies that if the positive effect of high unused tiering allowances on the supply of credit reflected banks' incentives to increase their reserve holdings in the post-implementation period, the increase in credit supply should be driven by banks with higher financing costs. We identify these banks as those that faced higher borrowing interest rates in the secured money market before the tiering implementation. In columns (1) and (2), we split the sample considering banks with borrowing rates above and below the median. The estimates show that banks with unused exemptions lent more only if they faced an interest rate above the median when borrowing in the money market. This finding supports our conjecture that the tiering system facilitates monetary transmission through banks that *ex ante* found it too costly to have higher reserve holdings. Column (3) confirms that the differences in lending behavior between banks are statistically significant. We also find some evidence that all banks with unused exemptions, regardless of the interest rate they faced, may have expanded the credit supply already when the tiering was first hinted in March 2019, albeit to a lower extent. This effect is not consistent across specifications (as seen in Table 9) but could suggest that reallocation of liquidity had slowly started when the introduction of the tiering became more likely.

Table 9 provides additional evidence on the cross-sectional differences in bank lending after the introduction of the tiering. In columns (1) and (2), we consider two alternative proxies for banks' *ex ante* funding costs, specifically bank capitalization and CDS spreads. Consistent with our earlier findings, the positive effects of the tiering system on bank lending appear to be driven by banks that had unused exemptions and low capitalizations or high CDS spreads. These findings further support our hypothesis that the tiering, by increasing the return of holding reserves, increased low-excess-liquidity banks' ability to withstand

Table 6
Alternative channels
The table shows how banks' lending to firms changes after the announcement and implementation of the tiering depending on the banks' exposure to the tiering system. The dependent variable in all columns is the logarithm of loans by bank *i* to a non-financial corporation *f* in month *t*. "Exposure(Feb 2019)" is equal to the unused exemption allowance (as a percentage of main assets) of bank *i* in February 2019 if such difference is positive, and to zero otherwise. "Exposure(Oct 2019)" is defined in the same way, but as of October 2019. The "Interim (Mar-Oct 2019)" variable is an indicator for the time between the speech by former ECB President Draghi on March 27, 2019, in which he hinted at the introduction of a tiering system for the first time, and the eventual implementation of the system as of October 30, 2019. "Implementation (Nov 2019-Feb 2020)" is an indicator variable for the time after October 30, 2019, i.e., the time when the tiering system took effect. Tiering benefits in February (October) 2019 are defined as $[\min\{0, DFR \times (EL - MRR \times 6)\} - DFR \times EL]/Assets$) in February (October) 2019. Control variables are as defined in Table 1, Panel B. The observation frequency in all regressions is monthly, and the sample period ranges from September 2018 to February 2020. Standard errors are clustered at the bank-time-period level. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1 %, 5 %, and 10 % level, respectively.

Dependent Variable: Volume of NFC loans	(1) Log	(2) Log
Exposure(Feb 2019)*Interim(Mar-Oct 2019)	0.012	0.015
	(0.010)	(0.012)
Exposure(Oct 2019)*Implementation(Nov 2019-Feb 2020)	0.069***	0.075***
	(0.020)	(0.023)
Tiering Benefits(Feb 2019)*Interim(Mar-Oct 2019)	0.553	
	(0.578)	
Tiering Benefits(Oct 2019)*Implementation(Nov 2019-Feb 2020)	0.970	
	(0.819)	
Excess liquidity(Feb 2019)*Interim(Mar-Oct 2019)		0.003
		(0.003)
Excess liquidity(Oct 2019)*Implementation(Nov 2019-Feb 2020)		0.005
		(0.004)
CDS	−0.043	−0.043
	(0.033)	(0.033)
Excess liquidity	0.006	0.006
	(0.004)	(0.004)
Holdings of government securities	0.037**	0.037**
	(0.016)	(0.016)
Deposit ratio	0.000	0.000
	(0.000)	(0.000)
TLTRO funds	0.003**	0.003**
	(0.001)	(0.001)
Firm-Month FE	Yes	Yes
Bank-Firm FE	Yes	Yes
Observations	10,256,326	10,256,326
R-squared	0.935	0.935

Table 7
Bank exposure to concurrent policies
The table shows a robustness check on how banks' lending to firms changes after the announcement and implementation of the tiering depending on the banks' exposure to the tiering system, considering changes in the relation between lending and other control variables. The dependent variable is the logarithm of loans by bank *i* to a non-financial corporation *f* in month *t* . "Exposure(Feb 2019)" is equal to the unused exemption allowance (as a percentage of main assets) of bank *i* in February 2019 if such difference is positive, and to zero otherwise. "Exposure(Oct 2019)" is defined in the same way, but as of October 2019. The "Interim (Mar-Oct 2019)" variable is an indicator for the time between the speech by former ECB President Draghi on March 27, 2019, in which he hinted at the introduction of a tiering system for the first time, and the eventual implementation of the system as of October 30, 2019. "Implementation (Nov 2019-Feb 2020)" is an indicator variable for the time after October 30, 2019, i.e., the time when the tiering system took effect. Control variables are as defined in Table 1, Panel B. Assets are reported in logs of € million. CET1 ratio is in percentage points. The observation frequency in all regressions is monthly, and the sample period ranges from September 2018 to February 2020. Standard errors are clustered at the bank-time-period level. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1 %, 5 %, and 10 % level, respectively.

Dependent Variable:	(1)	(2)	(3)	(4)	(5)	(6)
Volume of NFC loans	Log	Log	Log	Log	Log	Log
Exposure(Feb 2019)*Interim(Mar-Oct 2019)	0.014	0.014	0.020	0.018	0.020	0.023
	(0.018)	(0.009)	(0.017)	(0.016)	(0.017)	(0.018)
Exposure(Oct 2019)*Implementation(Nov 2019-Feb 2020)	0.061*	0.045***	0.070***	0.072**	0.074***	0.081***
	(0.033)	(0.016)	(0.025)	(0.028)	(0.027)	(0.028)
CDS	−0.051	−0.018	−0.039	−0.050	−0.011	−0.014
	(0.045)	(0.021)	(0.038)	(0.039)	(0.015)	(0.016)
Excess liquidity	0.011	−0.002	0.005	0.002	0.003	0.003
	(0.007)	(0.002)	(0.005)	(0.004)	(0.004)	(0.004)
Government securities	0.057***	0.024***	0.043***	0.035**	0.028**	0.031**
	(0.017)	(0.009)	(0.016)	(0.016)	(0.013)	(0.014)
Deposit ratio	−0.000	−0.000	−0.000	0.001	−0.000	0.000
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
TLTRO funds	0.003	0.002	0.003	0.004*	0.004	0.003
	(0.003)	(0.001)	(0.002)	(0.002)	(0.003)	(0.003)
Assets					−0.561	−0.625
					(0.453)	(0.456)
CET1 ratio						−0.033**
						(0.015)
CDS*Interim(Mar-Oct 2019)	−0.012	−0.007	−0.004	−0.005	−0.004	−0.002
	(0.013)	(0.007)	(0.012)	(0.010)	(0.016)	(0.016)
Excess liquidity*Interim(Mar-Oct 2019)	−0.006	0.005**	0.005	0.007*	0.005**	0.005*
	(0.007)	(0.002)	(0.004)	(0.004)	(0.002)	(0.002)
Government securities*Interim(Mar-Oct 2019)	−0.004	0.001	−0.000	0.002	0.001	0.000
	(0.006)	(0.003)	(0.005)	(0.005)	(0.005)	(0.005)
Deposit ratio*Interim(Mar-Oct 2019)	−0.000	0.000	0.000	−0.000	0.001	0.001
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
TLTRO funds*Interim(Mar-Oct 2019)	−0.000	−0.001	−0.002	−0.003	−0.001	−0.001
	(0.004)	(0.002)	(0.004)	(0.004)	(0.003)	(0.003)
Assets*Interim(Mar-Oct 2019)					0.000	0.002
					(0.011)	(0.011)
CET1 ratio*Interim(Mar-Oct 2019)						0.005
						(0.006)
CDS*Implementation(Nov 2019-Feb 2020)	−0.036	−0.022	−0.067	−0.065	−0.082	−0.083
	(0.067)	(0.029)	(0.066)	(0.067)	(0.068)	(0.068)
Excess liquidity*Implementation(Nov 2019-Feb 2020)	−0.006	0.009**	0.003	0.009	0.005	0.005
	(0.010)	(0.004)	(0.006)	(0.006)	(0.004)	(0.004)
Government securities*Implementation(Nov 2019-Feb 2020)	−0.004	0.002	0.007	0.007	0.008	0.005
	(0.011)	(0.005)	(0.010)	(0.011)	(0.009)	(0.008)
Deposit ratio*Implementation(Nov 2019-Feb 2020)	0.002*	0.001**	0.000	−0.000	−0.001	−0.001
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
TLTRO funds*Implementation(Nov 2019-Feb 2020)	0.010	0.002	0.009*	0.006	0.013*	0.014*
	(0.007)	(0.003)	(0.005)	(0.005)	(0.008)	(0.008)
Assets*Implementation(Nov 2019-Feb 2020)					−0.038*	−0.032
					(0.020)	(0.020)
CET1 ratio*Implementation(Nov 2019-Feb 2020)						0.019*
						(0.011)
Bank FE	Yes	Yes	Yes	–	–	–
Country-Month FE	Yes	-	-	-	-	-
Industry-Location-Size-Month FE	–	Yes	–	–	–	–
Firm-Month FE	–	–	Yes	Yes	Yes	Yes
Bank-Firm FE	–	–	–	Yes	Yes	Yes
Observations	35,356,355	34,338,371	10,353,666	10,256,326	9,574,874	9,539,179
R-squared	0.084	0.719	0.697	0.935	0.936	0.936

liquidity shocks, which in turn made them more inclined to lend.

Concerns have been raised that high reserves holdings may lead to excessive risk taking (Acharya and Rajan, 2023). In the remainder of Table 9, we thus explore whether high risk or less efficient borrowers obtained more credit. We observe that the increase in the supply of credit by banks with high unused exemptions was similarly distributed across borrowers with different risk, size, profitability, and productivity, even though firms with high leverage may have benefitted more (column (6)). Overall, the increase in credit does not seem to have brought about excessive risk-taking or inefficient allocation of credit.

6.3. Loan characteristics

Anacredit allows us to explore other aspects of loan supply. Table 10

Table 8
Changes in lending and banks' ex ante money market borrowing rates
The table shows results from difference-in-differences regressions of banks' lending to firms on exposure to the tiering system. In columns (1) and (2), banks are split depending on whether their borrowing rate in the secured money market in October 2019 was above or below the median. In column (3), we test for differences in lending behavior for banks with borrowing rates above and below the median in a pooled sample. "Exposure(Feb 2019)" is equal to the unused exemption allowance (as a percentage of main assets) of bank *i* in February 2019 if such difference is positive, and to zero otherwise. "Exposure (Oct 2019)" is defined in the same way, but as of October 2019. The "Interim (Mar-Oct 2019)" variable is an indicator for the time between the speech by former ECB President Draghi on March 27, 2019, in which he hinted at the introduction of a tiering system for the first time, and the eventual implementation of the system as of October 30, 2019. "Implementation (Nov 2019-Feb 2020)" is an indicator variable for the time after October 30, 2019, i.e., the time when the tiering system took effect. Control variables include CDS, excess liquidity, holdings of government securities, deposit ratio and TLTRO funds, and are as defined in Table 1, Panel B. The observation frequency in all regressions is monthly, and the sample period ranges from September 2018 to February 2020. Standard errors are clustered at the bank-time-period level. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1 %, 5 %, and 10 % level, respectively.

Dependent Variable:	(1)	(2)	(3)
	Subsample Banks with borrowing rates		
Volume of NFC loans	Above median	Below median	Pooled
Above median money market rate (Oct-2019):			
Exposure(Feb 2019)*Interim(Mar-Oct 2019)	0.010***		0.008**
	(0.002)		(0.003)
Exposure(Oct 2019) *Implementation(Nov 2019-Feb 2020)	0.152***		0.148***
	(0.016)		(0.009)
Below median money market rate (Oct-2019):			
Exposure(Feb 2019)*Interim(Mar-Oct 2019)		0.056*	0.044*
		(0.031)	(0.025)
Exposure(Oct 2019) *Implementation(Nov 2019-Feb 2020)		−0.005	−0.015
		(0.028)	(0.026)
Controls	Yes	Yes	Yes
Firm-Month FE	Yes	Yes	Yes
Bank-Firm FE	Yes	Yes	Yes
Observations	1,453,670	232,868	2,001,748
R-squared	0.938	0.957	0.942

shows that on average, the introduction of the two-tier system did not have a significant impact on lending rates, suggesting that banks largely internalised the change in the average remuneration of their liquidity holdings rather than passing it onto clients. However, there are important differences between banks. Banks with high unused exemptions that faced high *ex ante* interest rates in the money market not only increased the supply of credit, but also decreased loan rates.

Furthermore, in Table 11, we find that the implementation of the system translated into an increase in the maturity of bank loans by banks with more unused exemptions. The impact is expressed in days, so that every percentage point increase in unused exemptions translates into 25 days longer loan maturity. This is consistent with an improvement of the transmission mechanism associated with expectations of a prolonged low interest rate environment, which in turn enabled banks to lengthen the maturity of their loan portfolio, despite the low margins. Importantly, the effect is driven by banks with *ex ante* more unused exemptions, suggesting that more reserves and the consequent ability to withstand potential cash shortfalls made banks more inclined to commit to lend for longer periods. Also the increase in loan maturity is driven by banks with unused exemptions that faced higher borrowing rates in the money market in October 2019, before the tiering implementation. These *ex ante* financially constrained banks with high unused exemptions not only increased the supply of credit, but also extended their average loan maturity and decreased loan rates. Banks that faced borrowing rates below the median in October 2019 and whose demand for reserves was unlikely to be depressed by high funding costs before the tiering introduction, if anything, decreased their loan maturity.

If the tiering system, by increasing reserve holdings for banks that would potentially make use of them, indeed allowed banks to hold illiquid assets, it should also allow them to provide more insurance. We should thus observe that banks with unused exemptions, incentivised to hold more excess reserves, are also more inclined to take liquidity risk by extending credit lines after the implementation of the tiering system (in line with the conjecture by Acharya et al., 2023). Table 12 shows that banks with unused exemptions indeed extended more credit lines after the implementation of the tiering system. Both drawn (column (1)) and undrawn (column (2)) credit lines increased, leading to an overall increase in granted credit lines (column (3)). This increase was driven by banks with unused exemptions, which had stronger incentives to increase their reserve holdings, as captured by the interest rate these banks faced in the money market before the implementation period (columns (4) to (6)). As larger credit lines are associated with more and unpredictable future liquidity needs for a lender, this evidence is in line with our conjecture that the transmission mechanism is enhanced by the implementation of the tiering system because higher reserves reduced banks' precautionary behavior.

6.4. Firm-level borrowing and aggregate effects

Our conceptual framework assumes that banks with ex ante high excess liquidity and no unused exemptions have reached a satiation point and consequently do not change their lending policies after transferring liquidity through the money market. The evidence that the increase in the demand for reserves was not associated with higher rates in the money market and that high excess liquidity banks in Table 7 do not lend less supports our assumption.

To provide more direct evidence on the extent to which negative spillovers to the supply of credit of banks that transferred liquidity may have decreased the aggregate credit supply, we analyze the total amount of loans outstanding at the firm level. Table 13 shows that the amount of bank loans on the balance sheets of firms associated with banks more exposed to the policy increased. Importantly, the economic magnitudes for the increase in bank loan usage at the firm level are comparable with those reported in Table 5. Specifically, in column (1), a one-standard-deviation increase in the firm-level exposure to high-unused-exemption banks (equal to 1.95 in the firm-year panel) corresponds to an 8 percentage point increase in the (firm level) logarithm of the volume of outstanding loans, which is the same order of magnitude as the estimated effect in Table 5, where – depending on the specification – we estimate a relationship-level increase in exposure between 6 and 9.5 percentage points.

This evidence further supports the conclusion that the reallocation of liquidity towards banks with *ex ante* low reserve holdings occurred without a reduction in lending by the *ex ante* high excess liquidity banks that transferred reserves.

The impact of the increase in excess liquidity for banks with unused allowances on aggregate credit growth is therefore sizeable. The tiering led to an increase in the reserve holdings of low liquidity banks of around EUR 190bn (see Fig. 4). Using the conservative estimates in column (2) of Table 5, Panel A, a one-standard-deviation increase in unused exemptions (computed from the standard deviation of exposure in Table 1, Panel B) implies an increase in loan growth of 3.7%, which in turn translates into an increase in credit of about EUR 25bn, when applied to the credit to non-financial corporations of euro area banks in

Table 9

Bank and borrower cross-sectional differences

The table shows results from difference-in-differences regressions of banks' lending to firms on the banks' exposure to the tiering system. Each column reports two separate regressions. We report estimates for the subsamples above and below the median of the characteristic indicated in each column. The third panel in each column reports the value of the F test for the significance of the differences (resulting significance is indicated by the asterisks) between the coefficients in the regressions reported above. "Exposure(Feb 2019)" is equal to the unused exemption allowance (as a percentage of main assets) of bank *i* in February 2019 if such difference is positive, and to zero otherwise. "Exposure(Oct 2019)" is defined in the same way, but as of October 2019. The "Interim (Mar-Oct 2019)" variable is an indicator for the time between the speech by former ECB President Draghi on March 27, 2019, in which he hinted at the introduction of a tiering system for the first time, and the eventual implementation of the system as of October 30, 2019. "Implementation (Nov 2019-Feb 2020)" is an indicator variable for the time after October 30, 2019, i.e., the time when the tiering system took effect. Control variables include CDS, excess liquidity, holdings of government securities, deposit ratio and TLTRO funds, and are as defined in Table 1, Panel B. The observation frequency in all regressions is monthly, and the sample period ranges from September 2018 to February 2020. Standard errors are clustered at the bank-time-period level. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1 %, 5 %, and 10 % level, respectively.

Dependent Variable: Volume of NFC loans	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Sample splits by:	Bank capital	Bank CDS	Firm PD	Firm size	Firm ROA	Firm leverage	Firm productivity
High:							
Exposure(Feb 2019)*Interim(Mar-Oct 2019)	−0.005	0.015	0.001	0.009	0.008	0.009	0.013
	(0.004)	(0.012)	(0.012)	(0.008)	(0.008)	(0.008)	(0.008)
Exposure(Oct 2019)*Implementation(Nov 2019-Feb 2020)	0.003	0.081***	0.051***	0.058***	0.067**	0.071***	0.064***
	(0.007)	(0.022)	(0.017)	(0.020)	(0.028)	(0.022)	(0.022)
Low:							
Exposure(Feb 2019)*Interim(Mar-Oct 2019)	0.009	0.002	0.017	0.003	0.006	0.005	−0.000
	(0.007)	(0.011)	(0.012)	(0.008)	(0.007)	(0.008)	(0.008)
Exposure(Oct 2019)*Implementation(Nov 2019-Feb 2020)	0.068***	0.006	0.072**	0.070**	0.059***	0.052**	0.062**
	(0.023)	(0.018)	(0.029)	(0.029)	(0.019)	(0.023)	(0.026)
F-test: High = Low							
Exposure(Feb 2019)*Interim(Mar-Oct 2019)	3.19*	0.71	2.34	2.62	0.56	1.45	5.51**
Exposure(Oct 2019)*Implementation(Nov 2019-Feb 2020)	7.61***	7.04***	0.88	0.98	0.79	12.56***	0.04
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank-Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 10

Changes in lending rates

The table shows results from difference-in-differences regressions of the lending rates on banks' exposure to the tiering system. The dependent variable is the average lending rate for loans from bank *i* to non-financial corporation *f* in month *t*. In columns (2) to (4), banks are split depending on whether their borrowing rate in the money market in October 2019 was above or below the median across banks. "Exposure(Feb 2019)" is equal to the unused exemption allowance (as a percentage of main assets) of bank *i* in February 2019 if such difference is positive, and to zero otherwise. "Exposure(Oct 2019)" is defined in the same way, but as of October 2019. The "Interim (Mar-Oct 2019)" variable is an indicator for the time between the speech by former ECB President Draghi on March 27, 2019, in which he hinted at the introduction of a tiering system for the first time, and the eventual implementation of the system as of October 30, 2019. "Implementation (Nov 2019-Feb 2020)" is an indicator variable for the time after October 30, 2019, i.e., the time when the tiering system took effect. Control variables include CDS, excess liquidity, holdings of government securities, deposit ratio and TLTRO funds, and are as defined in Table 1, Panel B. The observation frequency in all regressions is monthly, and the sample period ranges from September 2018 to February 2020. Standard errors are clustered at the bank-time-period level. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1 %, 5 %, and 10 % level, respectively.

Dependent Variable: Interest rate on NFC loans	(1) Overall	(2) Above median	(3) Below median	(4) Pooled
Exposure(Feb 2019)*Interim(Mar-Oct 2019)	−0.017			
	(0.031)			
Exposure(Oct 2019)*Implementation(Nov 2019-Feb 2020)	0.041			
	(0.066)			
Above median money market rate (Oct-2019):				
Exposure(Feb 2019)*Interim(Mar-Oct 2019)		−0.013***		−0.015**
		(0.003)		(0.006)
Exposure(Oct 2019)*Implementation(Nov 2019-Feb 2020)		−0.048***		−0.046***
		(0.011)		(0.012)
Below median money market rate (Oct-2019):				
Exposure(Feb 2019)*Interim(Mar-Oct 2019)			0.195	0.156
			(0.235)	(0.159)
Exposure(Oct 2019)*Implementation(Nov 2019-Feb 2020)			0.372	0.312
			(0.401)	(0.315)
Controls	Yes	Yes	Yes	Yes
Firm-Month FE	Yes	Yes	Yes	Yes
Bank-Firm FE	Yes	Yes	Yes	Yes
Observations	10,256,326	1,453,670	232,868	2,001,748
	0.849	0.907	0.918	0.915

Table 11
Changes in loan maturity
The table shows results from difference-in-differences regressions of the loan maturity on banks' exposure to the tiering system. The dependent variable is the average residual maturity expressed in days for loans from bank *i* to non-financial corporation *f* in month *t*. In columns (2) and (3), banks are split depending on whether their borrowing rate in the money market in October 2019 was above or below the median across banks. "Exposure(Feb 2019)" is equal to the unused exemption allowance (as a percentage of main assets) of bank *i* in February 2019 if such difference is positive, and to zero otherwise. "Exposure(Oct 2019)" is defined in the same way, but as of October 2019. The "Interim (Mar-Oct 2019)" variable is an indicator for the time between the speech by former ECB President Draghi on March 27, 2019, in which he hinted at the introduction of a tiering system for the first time, and the eventual implementation of the system as of October 30, 2019. "Implementation (Nov 2019-Feb 2020)" is an indicator variable for the time after October 30, 2019, i.e., the time when the tiering system took effect. Control variables include CDS, excess liquidity, holdings of government securities, deposit ratio and TLTRO funds, and are as defined in Table 1, Panel B. The observation frequency in all regressions is monthly, and the sample period ranges from September 2018 to February 2020. Standard errors are clustered at the bank-time-period level. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1 %, 5 %, and 10 % level, respectively.

Dependent Variable: Maturity	(1) Overall	(2) Above median	(3) Below median	(4) Pooled
Exposure(Feb 2019)*Interim(Mar-Oct 2019)	3.029			
	(3.925)			
Exposure(Oct 2019)*Implementation(Nov 2019-Feb 2020)	24.789***			
	(6.306)			
Above median money market rate (Oct-2019):				
Exposure(Feb 2019)*Interim(Mar-Oct 2019)		−4.593**		−4.142***
		(1.804)		(1.541)
Exposure(Oct 2019)*Implementation(Nov 2019-Feb 2020)		23.562***		26.843***
		(1.820)		(2.196)
Below median money market rate (Oct-2019):				
Exposure(Feb 2019)*Interim(Mar-Oct 2019)			−22.346	−18.934
			(18.546)	(11.534)
Exposure(Oct 2019)*Implementation(Nov 2019-Feb 2020)			−30.895*	−34.745**
			(17.645)	(13.077)
Controls	Yes	Yes	Yes	Yes
Firm-Month FE	Yes	Yes	Yes	Yes
Bank-Firm FE	Yes	Yes	Yes	Yes
Observations	10,256,326	1,453,670	232,868	2,001,748
R-squared	0.966	0.907	0.918	0.915

Table 12
Credit lines
The table shows results from difference-in-differences regressions of banks' credit lines (drawn in columns (1) and (4), undrawn in columns (2) and (5), and overall in columns (3) and (6)) to firms on the banks' exposure to the tiering system. In columns (4) to (6), we distinguish between banks depending on whether their borrowing rate in the money market in October 2019 was above or below the median across banks. "Exposure(Feb 2019)" is equal to the unused exemption allowance (as a percentage of main assets) of bank *i* in February 2019 if such difference is positive, and to zero otherwise. "Exposure(Oct 2019)" is defined in the same way, but as of October 2019. The "Interim (Mar-Oct 2019)" variable is an indicator for the time between the speech by former ECB President Draghi on March 27, 2019, in which he hinted at the introduction of a tiering system for the first time, and the eventual implementation of the system as of October 30, 2019. "Implementation (Nov 2019-Feb 2020)" is an indicator variable for the time after October 30, 2019, i.e., the time when the tiering system took effect. Control variables include CDS, excess liquidity, holdings of government securities, deposit ratio and TLTRO funds, and are as defined in Table 1, Panel B. The observation frequency in all regressions is monthly, and the sample period ranges from September 2018 to February 2020. Standard errors are clustered at the bank-time-period level. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1 %, 5 %, and 10 % level, respectively.

Dependent Variable:	(1) Drawn credit lines	(2) Undrawn credit lines	(3) Overall credit lines	(4) Drawn credit lines	(5) Undrawn credit lines	(6) Overall credit lines
Exposure(Feb 2019)*Interim(Mar-Oct 2019)	−0.003	−0.009	−0.000			
	(0.007)	(0.008)	(0.006)			
Exposure(Oct 2019)*Implementation(Nov 2019-Feb 2020)	0.025**	0.020*	0.031***			
	(0.010)	(0.012)	(0.010)			
Above median money market rate (Oct-2019):						
Exposure(Feb 2019)*Interim(Mar-Oct 2019)				0.006*	−0.004	0.002
				(0.003)	(0.006)	(0.005)
Exposure(Oct 2019)*Implementation(Nov 2019-Feb 2020)				0.018**	0.020**	0.027***
				(0.007)	(0.008)	(0.008)
Below median money market rate (Oct-2019):						
Exposure(Feb 2019)*Interim(Mar-Oct 2019)				−0.016	0.099	−0.013
				(0.053)	(0.119)	(0.036)
Exposure(Oct 2019)*Implementation(Nov 2019-Feb 2020)				−0.041	0.186	0.046
				(0.056)	(0.125)	(0.031)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm-Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Bank-Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,936,816	3,910,966	5,779,814	929,340	724,860	1,143,426
R-squared	0.934	0.913	0.954	0.944	0.937	0.965

Table 13
Firm level borrowing
The table shows how loan volumes borrowed by firms changed after the announcement and implementation of the tiering depending on the firms' exposure to banks exposed to the tiering system. The dependent variable is the logarithm of loan volume borrowed by firm *f* in month *t* from all banks. All dependent variables are obtained by averaging the corresponding firm-bank-month level variables at the firm-month level, with weights equal to the exposures of each firm to each bank the month before, and are labeled with the prefix avg. In columns (1), (2) and (3), all firms are considered in the regression. In Columns (4) and (5), firms are split depending on whether the average borrowing rate in the secured money market in October 2019 of the banks each firm had exposures with the month before was above or below the median. "Exposure(Feb 2019)" is equal to the unused exemption allowance (as a percentage of main assets) of bank *i* in February 2019 if such difference is positive, and to zero otherwise. "Exposure(Oct 2019)" is defined in the same way, but as of October 2019. The "Interim (Mar-Oct 2019)" variable is an indicator for the time between the speech by former ECB President Draghi on March 27, 2019, in which he hinted at the introduction of a tiering system for the first time, and the eventual implementation of the system as of October 30, 2019. "Implementation (Nov 2019-Feb 2020)" is an indicator variable for the time after October 30, 2019, i.e., the time when the tiering system took effect. Control variables include CDS, excess liquidity, holdings of government securities, deposit ratio and TLTRO funds and are as defined in Table 1, Panel B. Observations are at the firm level. The observation frequency in all regressions is monthly, and the sample period ranges from September 2018 to February 2020. Standard errors are clustered at the main bank-time-period level, where the main bank for each firm is the one with the largest outstanding loan. Standard errors are reported in parentheses. ***, **, and * denote significance at the 1 %, 5 %, and 10 % level, respectively.

	(1)	(2)	(3)	(4)	(5)
Dependent Variable: Volume of NFC loans	Full sample	Full sample	Full sample	Banks with above median money market rate	Banks with below median money market rate
Avg Exposure(Feb 2019)*Interim(Mar-Oct 2019)	0.007	0.020	0.017	0.011	−0.003
	(0.010)	(0.017)	(0.020)	(0.016)	(0.016)
Avg Exposure(Oct 2019)*Implementation(Nov 2019-Feb 2020)	0.043**	0.056***	0.055***	0.141***	0.031*
	(0.019)	(0.019)	(0.039)	(0.016)	(0.016)
Avg CDS spread	−0.003	0.044***	0.046***	−0.060	0.041
	(0.013)	(0.016)	(0.016)	(0.045)	(0.028)
Avg Excess liquidity	0.003	0.008*	0.010**	0.017***	−0.005
	(0.002)	(0.005)	(0.004)	(0.007)	(0.004)
Avg Holdings of government securities	0.021***	0.022***	0.023***	0.026**	0.014
	(0.008)	(0.006)	(0.005)	(0.010)	(0.010)
Avg Deposit ratio	0.000**	0.001***	0.001***	0.002***	0.000
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)
Avg TLTRO funds	0.001	0.003*	0.003**	−0.004	0.000
	(0.001)	(0.001)	(0.001)	(0.003)	(0.002)
Firm FE	Yes	Yes	Yes	Yes	Yes
Country-Month FE	Yes			Yes	Yes
Main Bank-Month FE, Sector-Month FE, Location-Month FE		Yes			
Main Bank-Industry-Location FE			Yes		
Observations	26,206,015	26,205,638	25,237,538	8,357,258	6,865,878
R-squared	0.910	0.915	0.923	0.903	0.903

our sample exposed to the policy (around EUR 662bn). Thus, reallocating one euro of reserves from banks with high reserve holdings to banks with low reserve holdings increases lending by about EUR 15 cents.

7. Conclusions

We show that central bank liquidity affects the transmission of monetary policy. Specifically, a policy that incentivizes a redistribution of excess reserves towards banks with higher liquidity needs can effectively strengthen monetary policy transmission. The ECB's tiered reserve remuneration systems increased the gains from trading excess liquidity which led to a redistribution of reserves towards banks with higher liquidity needs. These banks became subsequently more likely to use their reserve holdings to support credit creation.

Our results imply that banks' decisions to hold low levels of liquidity, even if optimally taken at the individual level, may have undesirable aggregate effects. Banks that find it too costly to hold excess reserves may end up having uninsured future liquidity needs and may choose to limit lending. The tiering system, by increasing banks' incentives to hold liquidity, decreased their precautionary behavior, thereby benefitting the supply of credit to the real economy.

Our findings highlight the challenges faced by central banks engaging in quantitative tightening, particularly when liquidity is unevenly distributed across banks. While a reduction of reserves that mostly affects banks that have high liquidity holdings and have reached their satiation point is unlikely to have sizable negative effects on bank lending, a similar decrease in reserves affecting less liquid banks can have large contractionary effects. This makes the consequences of shrinking central banks' balance sheets difficult to predict.

CRediT authorship contribution statement

Carlo Altavilla: Writing – review & editing, Methodology, Conceptualization. **Miguel Boucinha:** Data curation. **Lorenzo Burlon:** Writing – review & editing, Methodology, Investigation, Data curation. **Mariassunta Giannetti:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Julian Schumacher:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation.

Declaration of competing interest

Carlo Altavilla declares that he has no relevant conflicts or material financial interests that relate to the research described in this paper.

Miguel Boucinha declares that he has no relevant conflicts or material financial interests that relate to the research described in this paper.

Lorenzo Burlon declares that he has no relevant conflicts or material financial interests that relate to the research described in this paper.

Mariassunta Giannetti declares that she has no relevant conflicts or material financial interests that relate to the research described in this paper.

Julian Schumacher declares that he has no relevant conflicts or material financial interests that relate to the research described in this paper.

References

Acharya, V.V., Eisert, T., Eufinger, C., Hirsch, C.W., 2019. Whatever it takes: the real effects of unconventional monetary policy. Rev. Financ. Stud. 32, 3366–341.

Acharya, V.V., Chauhan, R.S., Rajan, R.G., Steffen, S., 2023. Liquidity Dependence and the Waxing and Waning of Central Bank Balance Sheets. New York University. Working Paper.

Acharya, V.V., Rajan, R.G., 2023. Liquidity, Liquidity Everywhere, Not a Drop to Use - Why Flooding Banks With Central Bank Reserves May Not Expand Liquidity. New York University.

Afonso, G., Giannone, D., Spada, G.L., Williams, J.C., 2023. Scarce, Abundant, or Ample? A Time-Varying Model of the Reserve Demand Curve. Federal Reserve Bank of New York. Working Paper.

Afonso, Gara, Giannone, Domenico, Spada, Gabriele La, Williams, John C., 2024. When Are Central Bank Reserves Ample? Liberty Street, August 13.

Baldo, L., Hallinger, B., Helmus, C., Herrala, N., Martins, D., Mohing, F., Petroulakis, F., Resinek, M., Vergote, O., Usciati, B., Wang, Y., 2017. The distribution of excess liquidity in the euro area. In: ECB Occasional Paper No. 200.

Baldo, L., Heider, F., Hoffmann, P., Sigaux, J., Vergote, O., 2022. How do banks manage liquidity. In: ECB Working Paper No. 2732.

Bernanke, B.S., Lown, C.S., 1991. The credit crunch. Brookings Pap. Econ. Activity (2), 205–239.

Bottero, M., Minoiu, C., Peydró, J.-L., Polo, A., Presbitero, A., Sette, E., 2022. Negative monetary policy rates and portfolio rebalancing: evidence from credit register data. J. Financ. Econ. 146, 754–778.

Boucinha, M., Burlon, L., Corsi, M., Della Valle, G., Eisenschmidt, J., Marmara, I., Pool, S., Schumacher, J., Vergote, O., 2022. Two-tier system for remunerating excess reserve holdings. In: ECB Occasional Paper No. 302.

Chakraborty, I., Goldstein, I., MacKinlay, A., 2020. Monetary stimulus and bank lending. J. Financ. Econ. 136 (1), 189–218.

Cooperman, H., Duffie, J.D., Luck, S., Wang, Z., Yang, Y.D., 2022. Bank Funding Risk, Reference Rates, and Credit Supply. Stanford University. Working Paper.

Degryse, H., De Jonghe, O., Jakovljević, S., Mulier, K., Schepens, G., 2019. Identifying credit supply shocks with bank-firm data: methods and applications. J. Financ. Intermed. 40, 1–15.

Diamond, W., Jiang, Z., Ma, Y., 2024. The reserve supply channel of unconventional monetary policy. J. Financ. Econ. 159, 103887.

Di Maggio, M.D., Kermani, A., Palmer, C.J., 2020. How quantitative easing works: evidence on the refinancing channel. Rev. Econ. Stud. 87, 1498–1528.

Draghi, M., 2019. In: Monetary policy in the euro area. Speech at the conference 'The ECB and Its Watchers XX. Frankfurt am Main, 27 March.

Drechsler, I., Savov, A., Schnabl, P., Supera, D., 2024. Monetary policy and the mortgage market. In: Paper presented at the Jackson Hole Economic Symposium.

ECB, 2021. Euro Money Market Study 2020.

Eisenschmidt, J., Kedan, D., Tietz, R.D., 2018. Measuring fragmentation in the euro area unsecured overnight interbank money market. Econ. Bull. Articles 5 number 2.

Friedman, F., 1969. The optimum quantity of money. The Optimum Quantity of Money and Other Essays. Aldine, Chicago.

Fuster, A., Schelling, T., Towbin, P., 2021. Tiers of joy? Reserve Tiering and Bank Behavior in a Negative-Rate Environment, Working Papers 2021-10. Swiss National Bank.

Heider, F., Saidi, F., Schepens, G., 2019. Life below zero: bank lending under negative policy rates. Rev. Financ. Stud. 32 (10), 3728–3761.

Kandrac, J., Schlusche, B., 2021. Quantitative easing and bank risk taking: evidence from lending. J. Money, Credit Bank. 53 (4), 635–676.

Khwaja, A., Mian, A., 2008. Tracing the impact of bank liquidity shocks: evidence from an emerging market. Am. Econ. Rev. 98 (4), 1413–1442.

Krishnamurthy, A., Vissing-Jorgensen, A., 2011. The effects of quantitative easing on interest rates: channels and implications for policy. Brookings Pap. Econ. Act. 215.

Lane, P., 2023. Central bank liquidity: a macroeconomic perspective. In: Speech at the ECB Conference on Money Markets. November 9.

Logan, L. (2023). Ample reserves and the Friedman rule, November 10.

Lopez-Salido, D., Vissing-Jorgensen, A., 2023. Reserve Demand, Interest Rate Control, and Quantitative Tightening. Federal Reserve Board. Working Paper.

Rodnyansky, A., Darmouni, O.M., 2017. The effects of quantitative easing on bank lending behavior. Rev. Financ. Stud. 30 (11), 3858–3887.