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How do banks manage liquidity? Evidence from the ECB's tiering experiment

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Abstract

We study how banks manage their liquidity among the various assets at their disposal. We exploit the introduction of the ECB's two-tier system which heterogeneously reduced the cost of additional reserves holdings. We find that the treated banks increase reserve holdings by borrowing on the interbank market, decreasing lending to affiliates of the same group, and selling marketable securities. We also find that banks have a preference for a stable portfolio composition of liquid assets over time. Our results imply that frictions in one market for liquidity can spill over to several markets.

Keywords: Bank liquidity, central bank reserves; money markets; government bonds; monetary policy implementation

JEL Classification: G21, G11, E52

Non-technical Summary

This paper studies how banks manage their holdings of liquid assets. The study of banks' liquidity choices is an economically important question because it helps to shed light on spillovers across markets, on banks' risk management practices, and has implications for regulation and monetary policy implementation.

To shed light on banks' liquidity management, we study banks' reaction to a policy that heterogeneously reduced the cost of additional holdings of one particular type of liquid asset, namely central bank reserves. Specifically, we examine changes in banks' holdings of liquid assets around the introduction of the ECB's two-tier system on 30 October 2019. The policy change lowered the cost of additional reserves holdings only for the banks that were below a certain threshold.

Using a difference-in-differences framework, we show that these banks financed an increase in reserve holdings through a decrease in net lending in the money markets (1.5% of total assets), in the internal capital market (1.3% of total assets), as well as a decrease in securities holdings (0.6% of total assets). We find no evidence for systematic variation of these effects across countries.

We then relate banks' adjustment strategies with two different views of liquidity management, based on the literature on capital structure. More specifically, we contrast a "trade-off" view of liquidity where banks have a target portfolio composition resulting from balancing the costs and benefits of the various liquid assets, and a "pecking order" view where banks rely on a single liquid asset to finance reserves holdings. Using counterfactual simulations, we find support for the "trade-off" view of liquidity.

Our result of a trade-off in liquidity management has several implications for policy. First, as banks aim for a stable portfolio of liquid assets, their adjustment of reserve holdings can lead to spillovers across several markets. Second, however, the spillovers lead to smaller price pressures given that banks diversify their liquidity sources. Third, with banks' stable portfolios, a central bank can predict the impact of its actions on the markets for liquid assets. Finally, beyond the trade-off, our results show a smooth reallocation of reserves across the banking system.

1 Introduction

While the role of bank liquidity is well understood, the literature typically considers only one liquid asset. In reality, banks have various ways to obtain liquidity. They can hold central bank reserves, borrow in the interbank market, borrow within their banking group, or simply invest in government bonds. Considering only one liquid asset is therefore at odds with industry practice and, importantly, makes it difficult to ascertain the extent in which frictions in one market for liquidity spills over to other markets. In this paper, we fill the gap.

This paper studies how banks manage their liquidity among the various assets at their disposal. We exploit a shock that lowered the cost of additional holdings of one particular liquid asset, for some but not all banks. Specifically, we exploit the introduction in October 2019 of the ECB two-tier system for reserves ("tiering"). According to the new system, excess reserves holdings below a certain threshold were eligible to a lower holding cost. On the contrary, reserves above the threshold were not subject to the lower cost. Consequently, the two-tier system lowered the cost of additional reserves holdings solely for the banks whose level of holdings were below the threshold prior to October 2019.

The uneven impact of the two-tier system on banks' cost of holding reserves lends itself to a difference-in-differences approach. The treatment group are banks whose holdings are below the tiering threshold prior to the start of tiering. The control group are banks at the threshold. We estimate the causal effect of the cost of excess reserves on banks' holdings of three other liquid assets: interbank loans, intra-group loans, and marketable securities.

First, we find that the treated banks increased reserves by decreasing their holdings of interbank loans (1.5% of total assets), intra-group loans (1.3%), and marketable securities (0.6%). They achieved this new allocation by increasing money market borrowing, reducing lending to their affiliates, and selling domestic government bonds. In addition, we find that the banks above the two-tier threshold were their main counterparties on the money markets.

Second, we find that banks have a preference for a stable portfolio composition over time. Specifically, we fail to reject that the composition of banks' liquid portfolio was unaffected by the introduction of tiering, beyond the increase in reserves holdings. That is, we find that the relative weights of interbank loans, intra-group loans, and marketable securities is identical before and after tiering. This is an indication that the allocation of each asset is subject to a long-lasting cost/benefit trade-off, absent of pricing shocks.

Conversely, we find that banks do not have a pecking order among the various liquid assets. To reach that conclusion, we use counterfactuals to simulate a pecking order scenario where the entire amount of exempt reserves would be raised through a single source of liquidity. We reject that the actual and the counterfactual allocations are equal, even after taking into account possible borrowing constraints.

Studying banks' liquidity management is important to understand their role as intermediaries. Banks pool liquidity, issue liquid claims, and thereby allow individuals to access illiquid technologies (Diamond and Dybvig, 1983; Allen and Gale, 2004). The risk of a loss of liquidity can discipline banks (Calomiris and Kahn, 1991; Diamond and Rajan, 2001), but can also undermine them, especially in crisis times (Diamond and Rajan, 2005; Heider et al., 2015). This literature, however, typically considers only one liquid asset.

By considering more than one liquid assets, this paper is able to study banks' portfolio preferences. One possibility is that banks aim for a stable portfolio of liquid assets, whose composition results from a "trade-off" between the costs and benefits of each asset. In case of a price drop of one asset, a bank would increase its holdings of that asset without changing the relative proportions with which it holds the other liquid assets. Another possibility is that banks have a "pecking-order" of liquid assets. In that case, a bank would react by adjusting its holdings in a particular asset, and only change the holdings of other liquid assets once it has exhausted its capacity for the preferred type.

Our result of a trade-off in liquidity management has several implications. First, as banks aim for a stable portfolio of liquid assets, their adjustment of reserve holdings can lead to spillovers across several markets. Second, however, the spillovers lead to smaller price pressures given that banks diversify their liquidity sources. Third, with banks' stable portfolios, a central bank can predict the impact of its actions on the markets for liquid assets. Finally, beyond the trade-off, our results show a smooth reallocation of reserves across the banking system. The interbank supply of reserves proved to be elastic even though reserves are not spread evenly across banks in the euro area.

Related literature. Few papers study how banks manage their liquidity. DeYoung et al. (2018) study the liquidity behavior of commercial banks in response to negative capital shocks. They find that banks shift away from loans and increase their liquidity positions. DeYoung and Jang (2016) show that banks target regulatory liquidity ratios. Like these papers, we study how banks manage their liquidity. But unlike these, we study liquidity management across the different liquid assets.

Ihrig et al. (2019) study how banks manage the composition of their High-Quality Liquid Assets (HQLA). They find that banks adopt a risk-return strategy, where banks trade off the risk for the return of each of these assets. Like this paper, we study the composition of banks' liquid portfolios. Unlike them, we exploit a shock to pin down banks' strategies.

To the best of our knowledge, no other paper uses a shock on the cost of one liquid asset to study how banks manage their liquid portfolios. Fuster et al. (2021) study the introduction of a tiering mechanism in Switzerland and examine its impact on bank lending. Fuhrer et al. (2020) also study the Swiss tiering and, like us, find little adverse impact on the functioning of money markets, which points to the careful design of these tiering mechanisms by central banks. Bundesbank (2021) study the ECB two-tiering system. Like us, they find that some banks increase their reserves holdings, while other banks trade reserves with them. Unlike us, they limit their analysis to money market loans.

Our paper also relates to the distribution of reserves within the banking system. Ryan and Whelan (2021) report evidence suggestive of a "hot potatoe" effect, where banks attempt to push reserves away to other institutions. Chang et al. (2014) show that the accumulation of excess reserves is mainly driven by precautionary motives. Finally, Hoffmann and Sigaux (2020) find that excess reserves accrue on the balance sheets of banks with a low share of customer deposits, located in jurisdictions with lower sovereign bond yields, and high payments settlement activity.

Our results can help to develop realistic models of monetary policy implementation. Bianchi and Bigio (2021) provide a general equilibrium model of the macro-economy where the policy rate of a central bank transmits to short-term rates in the money market. In their model, banks trade-off holding liquid, low-yielding interbank loans and less liquid, but higher-yielding government securities. This is consistent with our results on how banks manage liquidity.

Finally, we borrow from the corporate finance literature on capital structure to rationalize how banks manage their liquidity. There are two broad theories to explain how firms manage their liabilities: the "trade-off" and the "pecking-order" theory (for a survey, see Frank and Goyal, 2008). According to the trade-off theory, firms have a preference for a stable (target) capital structure. Firms trade off the costs and benefits of debt and equity and hence, hold them in fixed proportions. In contrast, there is no target capital structure according to the pecking-order theory: firms prefer to issue debt over equity until they have exhausted their debt capacity.[1]

The rest of the paper is organized as follows. Section 2 introduces the policy experiment. Section 3 develops the hypotheses and introduces the data. Section 4 presents the empirical analysis. Section 5 presents the policy implications and concludes.

2 The policy experiment

The ECB implements its standard interest rate policy using a corridor system. More specifically, banks can borrow reserves overnight at the marginal lending facility (MLF) and deposit reserves at the deposit facility (DF). They can also borrow reserves at weekly Main Refinancing Operations (MRO) at a rate between the DF rate and the MLF rate.

[Insert Figure 1 here.]

The behaviour of short-term money market rates in a corridor system in which all participants have access to the central bank's balance sheet is well understood since the seminal work of Poole (1968). Bank's demand for liquidity fluctuates due to shocks arising from payment

[1]There is also a literature that studies how banks manage their liquidity in crisis times (e.g., Irani and Meisenzahl, 2017), including how banks engage in secondary trading of marketable assets during a crisis (Abbassi et al., 2016). Finally, there is a literature on the liquidity management of non-financial firms (for a survey, see Almeida et al., 2014). Banks' liquidity management, however, is different because of the special role of central bank reserves and other liquid assets for banks.

needs, and the central bank aims to offset these through regular open market operations. The prevailing rate depends on the probabilities assigned by banks of having to recourse to any of the ECB facilities, as illustrated in Panel A of Figure 1. Under balanced liquidity conditions with zero excess reserves, banks expect a recourse to either side of the corridor with equal probability so that market interest rates will be equal to the midpoint of the corridor (Bindseil, 2004). However, the ECB has created a large amount of reserves over the past years as a consequence of its non-standard monetary policy measures (e.g. asset purchases and long-term lending operations). As the supply of reserves increased, short-term interest rates became pinned down at the floor of the corridor, as shown in Panel B of Figure 1.

Importantly, the ECB implemented a negative interest rate policy from mid-2014 until mid-2022 by keeping the DF rate below zero. While the policy stimulates credit demand, it also entails significant reserves holdings costs for banks. Banks may find it hard to apply negative rates to e.g. household deposits, which can weigh on bank net interest rate margin. Looked at in isolation, a lack of full pass-through of interest rate cuts by the central bank to bank funding costs can negatively impact bank profitability.

In order to alleviate the pressures on bank profitability that emerge as a side effect of the negative interest rate policy, the ECB announced a two-tier system for the remuneration of excess reserves on 12 September 2019, with a starting date on 30 October 2019. Under this policy, banks are granted a partial exemption from the negative remuneration of excess reserves. More specifically, excess reserve holdings up to a bank-specific "allowance" (or "tiering limit") are remunerated at zero percent, and only further reserve holdings are subject to remuneration at the negative deposit facility rate (minus 50 bps as per 12 September 2019). The allowance changes the demand curve for reserves as illustrated in Panel A of Figure 2. Under the two-tier system,the relevant metric is no longer the amount of excess reserves but instead the amount of non-exempt excess reserves. That is, the amount of excess reserves that is not eligible for the zero percent remuneration rate. In particular, if the non-exempt amount of excess reserves is too small, money market rates may experience upward pressure towards the MRO rate.

The aim of the two-tier system is to provide relief to the banking system while maintaining the role of the DF rate as key anchor for short-term interest rates. In a frictionless market, a relatively modest amount of excess liquidity is sufficient for ensuring that the marginal value of reserves is equal to the remuneration on the deposit facility. However, the euro area interbank market is subject to significant frictions that may hinder a smooth circulation of excess reserves (Garcia-de Andoain et al., 2014). This is particularly relevant because excess reserve holdings in the euro area tend to be concentrated in certain jurisdictions (Baldo et al., 2017).

As a result, the ECB opted for a cautious calibration of the two-tier system in order to avoid unwanted upward pressure on short-term interest rates. To this end, the bank-specific allowance was set at six times the minimum reserve requirement. Based on the last reserve maintenance period (RMP) before the policy change, this corresponded to EUR 799 billion, or 46.7% of aggregate excess liquidity. Accordingly, excess liquidity remained ample so that short-term money market rates were likely to remain at the level of the deposit facility rate. The calibration also ensured that the amount of (cross-border) flows of reserves needed to fulfil unused allowances were relatively limited.

[Insert Figure 2 here.]

The adoption of the two-tier system went rather smoothly. Panel B of Figure 2 shows that banks acted swiftly towards making use of the exemption. In the sixth RMP, the theoretically unused allowance was around 227 billion EUR (28% of the total theoretical allowance). After the policy came into effect, the unused allowance shrank to EUR 37 billion in the seventh RMP (less than 5% of the total allowance) and continued shrinking afterwards. Panel C of Figure 2 illustrates that short-term money market rates were largely unchanged around the introduction of the measure, and any price effects were extremely short-lived. As market rates remained broadly stable, one can conclude that the two-tier system changed the price of only one asset, namely the price of the exempted part of banks' excess reserves.

[Insert Figure 2 here.]

3 Hypotheses and Data

In this Section, we first detail how the ECB's tiering policy can be used to test two competing hypotheses concerning banks' preferences over different sources of liquidity. We then discuss the data that we use to take these hypotheses to the data.

3.1 Hypotheses

The aim of our analysis is to shed light on how banks' manage liquidity. In practice, banks hold liquid assets for risk management purposes (liquidity buffer) and to comply with liquidity regulation. Different sources of liquidity exhibit different characteristics, which in turn may affect banks' preferences over the various alternatives. For example, marketable securities may be exposed to interest rate and credit risk, but also deliver convenience yield due to collateral eligibility and other features. By contrast, central bank reserves do not carry any of these features, while money market loans typically carry little interest rate risk and no convenience yield.

The adoption of the ECB's two-tier system constitutes an excellent laboratory for studying banks' preference over different sources of liquidity. The policy experiment led to an exogenous change in the value (i.e. remuneration) of one particular liquid asset, namely central bank reserves. Importantly, as shown above, it did *not* have a material effect on other short-term interest rates, suggesting that market liquidity was sufficient to keep the relative prices of other liquid assets broadly constant.

Accordingly, we expect banks to re-allocate their liquidity towards reserves, and the means through which they raise the required funds inform us about their preferences. We first conduct a standard difference-in-differences (DiD) analysis in order to estimate the treatment effects resulting from the policy change. We then drill down deeper in order to test competing hypotheses concerning bank behaviour.

To this end, we borrow from the literature on capital structure. In particular we contrast two views. Under the "trade-off" view, banks have a "target" portfolio (or structure) of liquidity sources, and thus raise liquidity in a proportional way. By contrast, the "pecking order" postulates that banks' have a strict preference for raising liquidity through one particular channel. This gives rise to the following two competing hypotheses in the context of the ECB's two-tier system.

Hypothesis A (Trade-off): Banks raise liquidity proportionally across various sources of liquidity, leaving their relative weights on the balance sheet unchanged.

Hypothesis B (Pecking order): Banks raise liquidity through one particular source.

3.2 Data

Before we introduce the data, we discuss banks' potential sources of liquidity. To keep matters simple, we focus on three groups of balance sheet items aside from central bank reserves. First, banks can obtain liquidity through the money market. They can do so either by borrowing additional funds from other market participants, or by reducing their own lending activity. Since both actions raise liquidity, we focus on *net* lending to the financial sector (loans minus deposits). Second, banks can alternatively resort to the internal capital market within their banking group. Following the same reasoning as above, we focus on *net* lending to group affiliates (loans minus deposits). Third, we consider banks securities holdings as our final source of liquidity. Banks typically hold marketable securities as part of their liquidity management strategies. In addition, a significant share of their securities portfolio consists of high-quality liquid assets (HQLA), and thus also constitutes a close substitute to central bank reserves from a regulatory perspective.

We obtain monthly bank-level balance sheet data for the period May 2019-Feb 2020 from a proprietary database maintained at the ECB (Morandi et al. (2016)). These data form the basis for the ECB's analysis of bank lending conditions, and the underlying sample is chosen to provide a representative coverage across jurisdictions and business models.

Since part of our analysis builds on a DiD framework, we allocate banks into treatment and control groups. To define these groups, we first collect all banks whose excess reserve holdings are below (above) their tiering allowance and call them "below-limit" ("above-limit") banks. We then assign banks to the treatment group if their unused allowance is above the 25th percentile of all "below-limit" banks. Similarly, we assign a bank to the control group if their unused allowance is below the 25th percentile of the "below-limit" and above the 75th percentile of the "above-limit" banks.[2] Intuitively, the control group consists of banks whose excess reserve holdings are close to their tiering allowance, such that they do not have any incentives to significantly alter their balance sheet as result of the policy change. Figure 3 graphically illustrates the approach used to select the treated and control groups.

[Insert Table 1 and Figure 3 here.]

Table 1 provides some basic summary statistics for our sample banks as of September 2019 (the last observation before the adoption of tiering). The average treated (control) bank has 69.3 (107.5) billion EUR in total assets. Reserves account for 2.1 (3.3)% of treated (control) banks' total assets. Treated and control banks have similar levels of customer loans (48.3-49.3%), securities holdings (19.0%), financial loans (15.6-18.8%), and book equity (9.4-10.8%). By contrast, the two groups differ in terms of customer deposits (53.8% vs. 38.2%) and debt securities issued (4.5% vs. 13.4%). Moreover, banks in the control group are net borrowers in the money market (-10.1%) and the internal capital market (-5.3%) whereas banks from the treated group have a broadly balanced position in the money market (-1.5%) and are net lenders vis-a-vis affiliates (2.8%). By construction, the control group has an almost zero unused tiering allowance (-0.4%), while the treated group has positive unused allowances (2.8%).

4 Empirical analysis

This Section contains the main empirical analysis. We start with a standard difference-in-differences (DiD) procedure aimed at estimating the average treatment effect on banks' holdings of various sources of liquidity. We then proceed to testing Hypotheses A and B by zooming in on the below-limit banks and conducting counterfactual exercises.

[2] Note that the unused allowance of "above-limit" banks is negative by definition.

4.1 Average treatment effect

Let $Y_{i,t}$ denote bank i's balance sheet position in a particular source of liquidity (e.g. net financial loans) during month t. We then estimate

$$Y_{i,t} = \alpha_i + \gamma_{c,t} + \delta(Treated_i \times After_t) + \epsilon_{i,t}, \tag{1}$$

where $Treated_i$ is a dummy variable equal to one for treated banks, and zero for control banks, and $After_t$ is a dummy variable that is equal to one from end of October 2019 onwards, and zero otherwise.[3] We saturate the model with bank and country-time fixed effects. The latter allow us to account for time-varying cross-country heterogeneity in sovereign credit risk and local lending opportunities, which are of particular relevance in the euro area. As usual, the coefficient on the interaction term measures the causal treatment effect.

[Insert Table 2 here.]

Table 2 reports the coefficient estimates from the estimation of equation (1) for our three sources of liquidity, where standard errors are clustered at the bank level. For the money market, we estimate an average treatment effect of -1.48 in column (2), which is statistically significant at the 1% level. This implies that, relative to the control group, the average treated bank raised close to 1.5% of total assets in excess reserves through a decrease in net lending to the financial sector. We discuss a decomposition of this effect into lending and borrowing further below. In column (2), we find a coefficient of -1.26 for the internal capital market, which is statistically significant at the 1% level. Accordingly, the launch of tiering caused an average reduction in net lending to affiliates by circa 1.3% of total assets. Finally, column (3) shows a decline in securities holdings of 0.6%, which is statistically significant at the 5% level.

Figure 4 graphically illustrates our estimated treatment effects by plotting the evolution for each group of balance sheet items for treatement and control groups. For better readability, each series has been normalized to average zero in the pre-event window. In the Online Appendix, we

[3] We obtain qualitatively similar results when estimating an alternative specification that allows for a continuous treatment variable. See Table A.1 in the Online Appendix for details.

additionally report results from two placebo tests, which supports the validity of the underlying "parallel trends" assumption.

[Insert Figure 4 here.]

It is instructive to consolidate the results across all three sources of liquidity. In sum, the average bank has raised liquidity corresponding to 3.4% of total assets.[4] Our coefficient estimates suggest show that 44% was raised in the money market, 37% in internal capital markets, and 19% through the sale of securities.

Next, we analyze the subcomponents of banks' money markets and internal capital market activity. In principle, banks can raise liquidity by either an increase in borrowing or a decrease in lending. We thus re-estimate equation (1) separately for each subcomponent. Table 3 reveals that banks raise excess reserves in the money market mostly via the liability side of their balance sheet. The coefficient estimate for borrowing is equal to 1.05 and statistically significant at the 1% level. While the coefficient for lending has the expected negative sign, consistent with an effort to raise liquidity, its magnitude is only about half, and statistically insignificant.

For the internal capital market, the coefficient estimates for borrowing and lending are both statistically significant and have the same magnitude (0.629). However, this effect may be in part mechanical because treated and control banks may be part of the same group. To alleviate this concern, we construct an alternative control group by removing affiliates of treated banks. Columns (5) and (6) show the resulting coefficient estimates. We find the adoption of the two-tier system induced banks to significantly curtail their intragroup lending (coefficient estimate -0.745%). By contrast, it did not affect intragroup borrowing.

[Insert Table 3 here.]

Next, we drill down on banks' securities holdings and estimate separate treatment effects for three different categories of asset holdings. We differentiate between domestic government bonds, non-domestic euro-area government bonds, and other securities (defined as non-euro area government bonds, other debt securities, money market funds, and equities). Table 4

[4] This closely corresponds to the difference in the unused allowances of the treatment and control groups, which is equal to 3.2%.

reveals that we only obtain a statistically significant treatment effect for domestic government bonds, through which banks raised liquidity corresponding to 0.31% of total assets. While we observe a coefficient estimate with a similar magnitude for non-domestic government bonds, the effect is not statistically significant, possibly due to substantial variation in banks' holdings of such securities. Finally, the coefficient associated with other securities is small in magnitude, and not statistically significant.

[Insert Table 4 here.]

We additionally examine whether and how tiering affected banks that were above the tiering limit. This is important for internal consistency. Central bank reserves circulate in a closed system, so we expect the above-limit banks to be providers of the reserves raised by treated banks (up to errors introduced by incomplete coverage of our sample). We use the same DiD specification as before, but now replace the treatment group with the set of banks whose reserve holdings exceed the tiering allowance and that are not part of the control group.[5] Table 5 reports the results. As predicted, the coefficient associated with net money market lending is positive and significant, consistent with above-limit banks provided excess reserves. The coefficient estimate is equal to 1.04, and statistically significant at the 5% level. This coefficient compares with a 1.5% decrease in net lending of below-limit banks reported in column (1) of Table 2. The difference in the coefficient magnitudes is likely to be due to the relatively larger size of above-limit banks, since all items are expressed as a fraction of total assets. For completeness, we also study these banks' intragroup lending and security holdings. Column (2) and (3) indicate that the coefficients for net intragroup lending and securities holdings are not statistically significant. This implies in particular that above-limit banks did not purchase the securities of treated banks. They may have been purchased by non-banks, or non-euro area banks.

[Insert Table 5 here.]

[5] Following the discussion in Section 3.2, these are banks whose unused allowance is below the 75th percentile of the distribution of all "above-limit" banks.

In order to give credence to our selection of liquidity sources, we provide additional results for other categories of assets and liabilities in the Online Appendix. Table A.3 shows that banks did not decrease their lending to customers to raise additional reserves, nor did they increase their issuance of debt securities or equity. This is consistent with these sources being more costly or more difficult to be used, especially in the short term. One exception is the finding that treated banks experienced a 1% decline in customer deposits. However, this result is unlikely to be associated to tiering. First, deposit flows are the result of customers' actions and thus to some extent outside of banks' control. Second, perhaps more importantly, a decrease in customer deposits consumes—rather than provides—excess liquidity.

In the Online Appendix, we investigate potential heterogeneity in treatment effects across our sample banks. We study how banks' liquidity rebalancing differs with country characteristics, investment opportunities and bank characteristics. More specifically, we study the impacts of residing in a vulnerable country, of the domestic government bond yield, bank size, the leverage ratio, as well as a measure of the bank's connectedness in the banking network. We find no evidence for any heterogeneity along these lines, with the exception of the leverage ratio. A higher leverage ratio is associated with more money market borrowing, consistent with choices being influenced by banks preferences for leverage.

4.2 Banks' preferences over liquid assets - Hypothesis tests

In this section, we provide formal tests based on counterfactual simulations that allow us to differentiate between the "trade-off" view and the "pecking order" view of banks' liquidity management. We begin by conducting a counterfactual exercise that simulates a "trade-off" situation, where a bank keeps constant its allocation across the various sources of liquidity. First, consider the asset side. We can represent a bank's allocation among the three different liquidity sources by means of the vector $\mathbf{a} = (a^{MM}, a^{IM}, a^{S})$, where the superscripts MM, IM, and S refer to money market lending, the intragroup lending, and securities holdings, respectively. In order to capture the relative allocation, we express each liquidity source relative to the total sum among all liquity sources, so that all elements of $\mathbf{a}$ sum up to unity.[6]

For each bank we generate a 'trade-off" counterfactual post-event allocation which is simply equal to the banks' pre-event allocation. We then test the hypothesis $\mathbf{a}_{Post} = \mathbf{a}_{Pre}$, where the subscripts refer to the average pre- and post-event allocations based on a 6-month window, respectively. We do so by means of Hotelling's t-squared test, which is a simple generalization of the t-test to a multivariate setting. The same can be done for the liability side, which can be represented by a 2-element vector $\mathbf{l} = (l^{MM}, l^{IM})$, thus giving rise to testing $\mathbf{l}_{Post} = \mathbf{l}_{Pre}$.[7]

Next, we conduct counterfactual exercises that directly simulate a "pecking order" situation where a bank raises all reserves via a given liquidity source. In detail, we generate a counterfactual allocation by subtracting (adding) the entire amount of additional reserves raised by a bank from (to) the bank's pre-tiering holdings of a particular asset (liability).[8]

This yields a total of five "pecking-order" counterfactuals, three for the asset side and two for the liability side. For each of them we test the hypothesis $\mathbf{a}_{Post} = \mathbf{a}_C$ or $\mathbf{l}_{Post} = \mathbf{l}_C$, where the subscript C indicates the simulated counterfactual allocation. Figure 5 graphically illustrates the counterfactual methodology.

[Insert Figure 5 here.]

Column (1) of Table 6 presents the results of the hypothesis tests for banks' relative allocation, where Panel A refers to the asset side, while Panel B relates to the liability side. Note that, by definition, the sum of the coefficients is equal to zero. Note also that the sample includes below-limit banks, and is additionally restricted to institutions that can be identified as being part of a banking group.[9] In both the asset and the liability sides, we fail to reject the null hypothesis that the relative pre- and post-event allocations across the three different

[6]That is, $a^{MM} = (Money\ Market\ Lending)/(Money\ Market\ Lending + Intragroup\ Lending + Securities\ Holdings)$, with accordingly similar definitions for a^{IM} and a^{S}.

[7]Note that securities holdings typically do not enter the liability side. While short positions would in principle a possibility, they are not economically meaningful.

[8]If the amount of raised reserves would yield a negative holding on the asset side, we first fully exhaust the liquidity source at the top of the pecking order, and then allocate the remaining liquidity among the other sources of liquidity according to their relative pre-event proportions. Our headline results are robust to various alternative methodologies.

[9]We require that we can either identify a parent or a subsidiary, or alternatively that the bank reports a non-zero intragroup position at least once during the May 2019 - February 2020 period.

sources of liquidity are identical, with p-values of 0.257 and 0.441. In detail, we observe a positive deviation in securities holdings and a small negative deviation in money market lending (asset side) relative to the pre-tiering allocations, but the magnitudes are small (0.7% and -0.6%, respectively). There is also a very small negative deviation in money market borrowing (liability side) of 0.2%. In sum, these findings suggest that banks did not change their relative allocations across the various different liquidity sources, but instead adjusted them proportionally to their pre-event holdings. This observations is consistent with the "trade-off" view of liquidity management.

[Insert Table 6 here.]

Columns (2) to (4) in Table 6 display the results from the "pecking-order" counterfactual exercise. We reject the "pecking order" view of liquidity management across the board at any conventional significance level. For example, column (2) in Panel A reports the extent to which the average post-tiering allocation on the asset side differs from the counterfactual allocation that would arise if banks had a strict preference for raising reserves through a reduction of money market loans. This difference is given by $\hat{\mathbf{a}}_{Post} - \hat{\mathbf{a}}_C = (3.535, -0.674, -2.861)$, which is statistically significant with an F-statistic of 21.36 and a resulting p-value of less than 0.001. Intuitively, banks have a too large position in money market loans relative to the counterfactual.

Taken together, our results provide strong support for the "trade-off" view under which banks raise liquidity for reserves proportionally across the various sources available to them, trading off costs and benefits. By contrast, we soundly reject the idea that banks have a strict preference for a particular instrument, e.g. money market borrowing.

One potential concern related to our counterfactual exercise is a failure to impose economically relevant constraints that may give rise to incorrect inferences. Suppose, for example, that a bank faces limitation on the funds that it can borrow from affiliates. A bank with a strong preferences for raising liquidity through this channel would then borrow until the limit, and subsequently revert to other sources, e.g. the money market. In such a situation, the econometrician might erroneously reject the hypothesis that the bank has a preference for intragroup borrowing.

We conduct a simple robustness test to take such constraint into account. We assume that a bank can only borrow from affiliates as long as those have an aggregate excess liquidity position that exceeds their aggregate tiering allowance. Intuitively, groups with scarce reserves are not able to lend them to affiliates, since it would imply a pointless zero-sum game. Accordingly, we modify our counterfactual exercises on the liability side so that they take these internal market borrowing constraints into account. If banks run into these constraints, the remaining liquidity is partly allocated to money market deposits. Note that the robustness test runs on a reduced sample since that we require each sample bank to have at least one affiliate in our dataset so as to be able to compute the group's liquidity position.

[Insert Table 7 here.]

The results after implementation of these constraints are shown in Table 7. While we observe a reduced distance between the actual and counterfactual allocations in the case of intragroup borrowing in column (3), we continue to reject the "pecking order" view at any conventional significance level.

Finally, we study heterogeneity across banks with respect to liquidity preferences. We do so by regressing the absolute value of the residuals from the trade-off analysis on a series of bank and country characteristics. More precisely, for each bank, we retrieve $\mathbf{a}_{Post} - \mathbf{a}_{Pre}$, as defined above. On the asset-side, we then take the sum of the absolute value of the two first components (Money market and Internal market allocations). We call this variable "trade-off residual". A high (low) trade-off residual indicates that the bank's liquidity preferences are less (more) consistent with the trade-off view of liquidity management. Similarly, on the liability side, we take the absolute value of the first component (money market).

We consider two types of explanatory variables. First, we capture diversity in bank business models using the ratio of customer deposits to total assets, and the (log) ratio of customer loans to securities holdings. Second, we analyze the role of cross-country variation using a set of country dummies.

Table 8 displays the results of our heterogeneity analysis. Column (1) shows that a higher loan to securities ratio is associated with higher residuals, suggesting that banks with a more traditional asset side (loans instead of securities) are more likely to deviate from the "trade-off" view of liquidity. By contrast, a higher reliance on deposit funding is associated with smaller residuals. We observe broadly similar results for assets and liabilities, and the magnitudes are also economically significant.[10] Note that the R-squared is relatively modest at 5-7%, suggesting a limited role for bank business models in explaining heterogeneity in liquidity preferences.

In column (2), we examine the role of country dummies. The R-squared ranges from 19% to 25%, suggesting that a significant part of the overall cross-sectional variation is explained by country factors. In column (3), we add the bank characteristics to the country dummies. Interestingly, the coefficients on the business model variables are qualitatively similar to column (1), and the R-squared is approximately equal to the sum from the previous two columns. This suggests that the explanatory power of both sets of variables is largely unrelated. In sum, bank business models and country factors explain around one third of the variation in banks' liquidity preferences.

5 Policy implications and conclusion

We study how banks manage their liquidity among the various liquid assets at their disposal. We exploit the introduction of the ECB's two-tier system which heterogeneously lowered the cost of increasing reserves holdings. We find that the treated banks chose to increase their reserves holdings by borrowing more on the money market, by shrinking their net intragroup loan book, and by reducing their marketable security holdings more than the unaffected banks. Futhermore, we find that banks have a preference for a stable portfolio composition of liquid assets over time, possibly resulting from balancing the costs and benefits of the various liquid assets. Conversely, we do not find that banks have a pecking order among the various liquid assets.

We derive the following policy implications from our findings that banks have a trade-off approach to liquidity management. First, a shock to the cost of holding reserves has spillovers into several markets, including security markets. This is an important result because monetary

[10] For example, a one standard deviation increase in the loan-to-security ratio is associated with an increase of circa 0.25 standard deviations of the residual on either side of the balance sheet.

policy is often conducted by changing the cost of holding reserves. One implication is that, in case the central bank sets the exemption allowance at a high level, the price in securities markets could be affected.

Second, banks spread the shock over several markets. Consequently, upward interest rate pressures in those markets is more limited than if banks were focusing on a single source of liquidity. This alleviates some of the concerns associated with the introduction of tiered remuneration of reserves.

Third, banks' constant allocation across the various sources of liquidity allows the policy maker to predict the impact of a change in the cost of holding reserves on trading volumes. In particular, the policy maker can make predictions of the impact of a potential increase in the tiering multiplier.

Finally, the supply of reserves has elastic features. Indeed, banks managed to fill their exempt allowance rather swiftly and without affecting market pricing. Banks with ample reserves did not hoard reserves despite the high concentration of reserve holdings among banks in the euro area.

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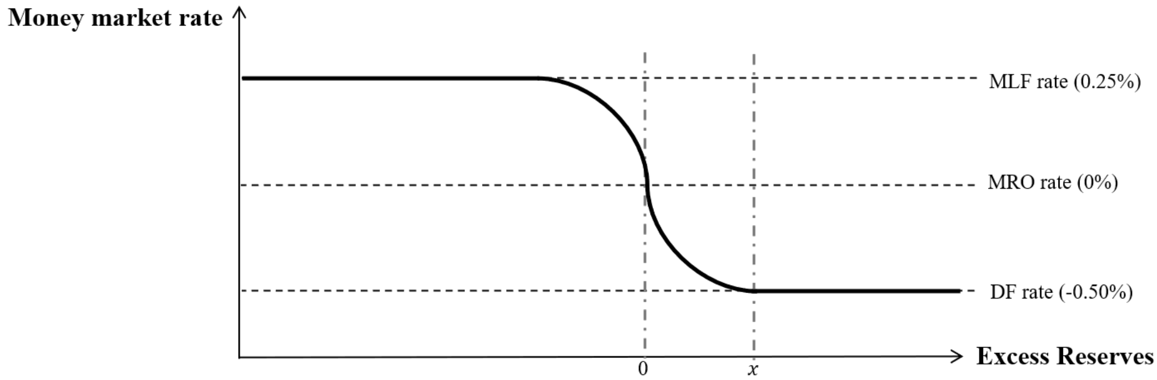
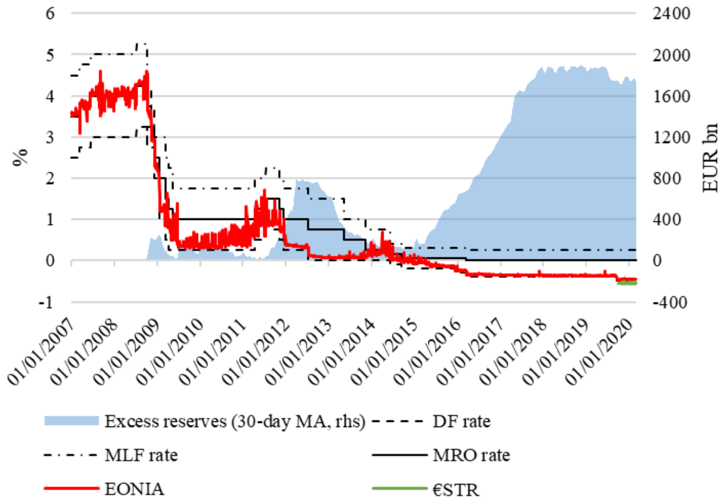
A Figures and Tables

Figure 1: ECB rate control

Panel A: The corridor system



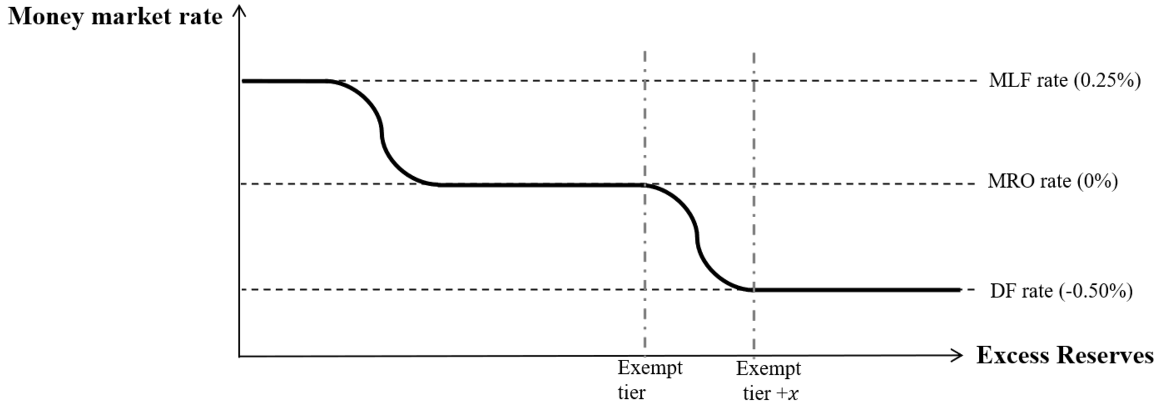
Panel B: Excess reserves and money market rates



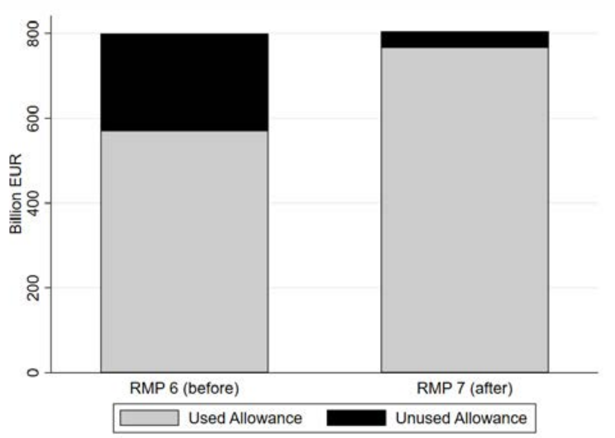
Panel A illustrates the relationship between short-term rates (y-axis) and the amount of reserves (x-axis) in a corridor system of monetary policy implementation. Panel B depicts the relationship between excess reserves and money market rates. Until 30 September 2019, EONIA computed as an interbank overnight lending rate. From 1 October 2019, EONIA computed as €STR + 8.5 bps. €STR is the euro risk-free rate and it is computed as an unsecured overnight bank borrowing rate from financial corporations.

Figure 2: Corridor system, allowance uptake and short-term interest rates under the two-tier system

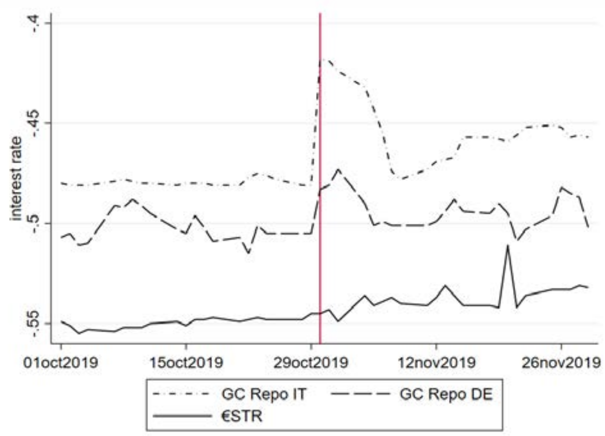
Panel A: The corridor system under the two-tier system



Panel B: Allowance uptake

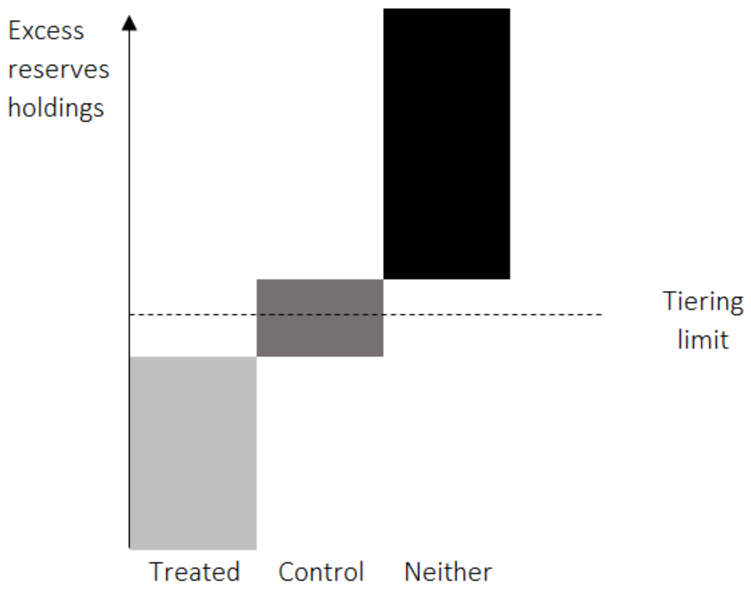


Panel C: Money market rates around the introduction of Tiering



Panel A illustrates the relationship between short-term rates (y-axis) and the amount of reserves (x-axis) in a corridor system of monetary policy implementation under the two-tier system. Panel B depicts banks' uptake of the tiering allowance for the entire euro area. The total height of each bar corresponds to the total aggregate allowance, while the area shaded in grey (black) represents the used (unused) proportion. The left (right) bar represents the average value on the sixth (seventh) reserve maintenance period (RMP), i.e. the last (first) RMP before (after) the policy change. Panel C depicts the evolution of interest rates from 1 May - 28 February 2020, where the vertical line marks the date of the policy change. *€STR* denotes the Euro short-term rate, a benchmark interest rate for unsecured borrowing by banks. *GC Repo IT* and *GC Repo DE* denote General Collateral Repo Rates based on Italian and German collateral baskets, obtained from Brokertec.

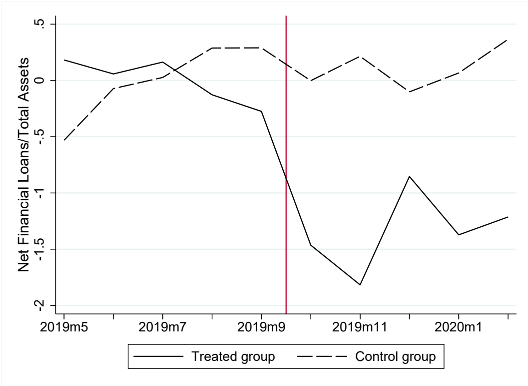
Figure 3: Illustration of the treated and control groups selection



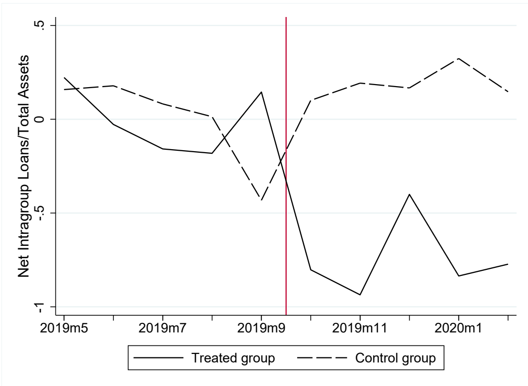
This figure illustrates the approach taken to select the treated and control groups. The treated group is made of banks which holdings of excess reserves is far below the tiering limit. The control banks are those with holdings of excess reserves that are slightly above or below the tiering limit. The banks with holdings that are far above the tiering limit are neither in the treated nor in the control groups. More precisely, treated banks are below-limit banks with unused allowance above the 25th percentile of all below-limit banks. Control banks are below the 25th percentile of the distribution of the unused allowance of below-limit banks, or above the 75th percentile of the distribution of the unused allowance of above-limit banks.

Figure 4: Difference-in-difference estimates

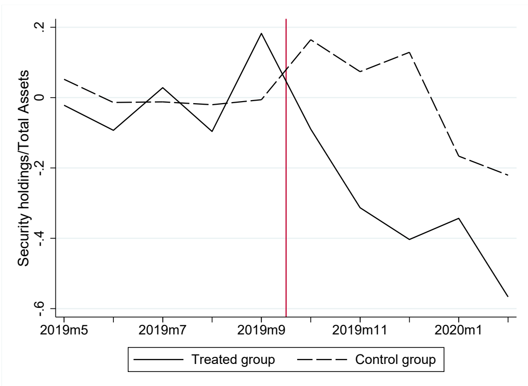
Panel A: Money Market



Panel B: Internal Capital Market



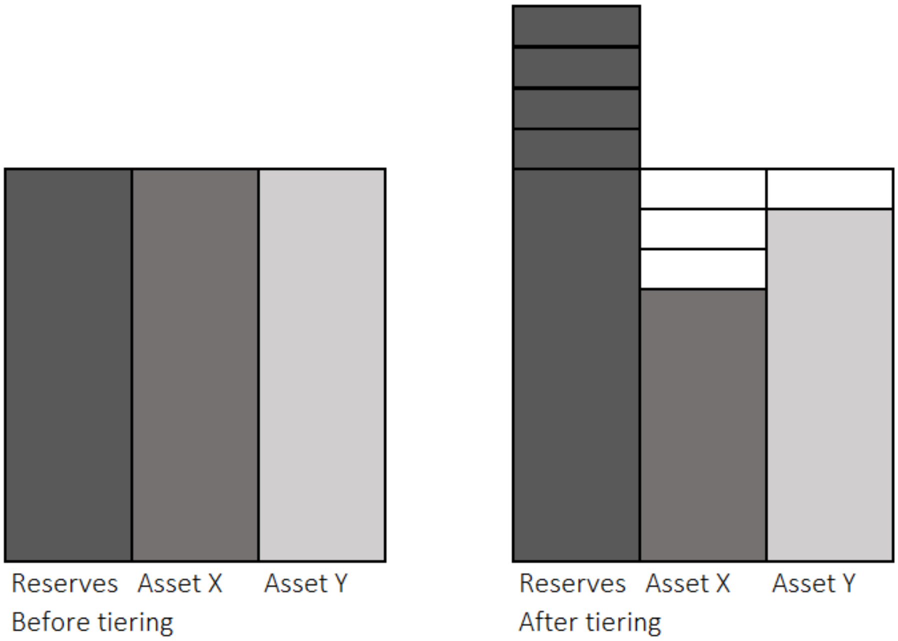
Panel C: Securities holdings



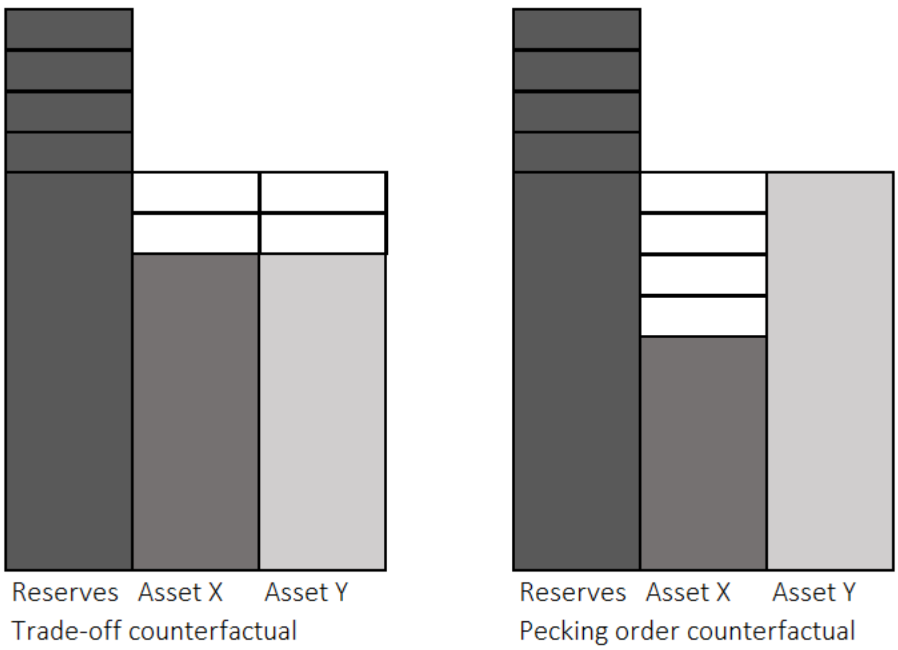
This figure depicts the cross-sectional averages for treatment and control groups for three sources of net liquidity holdings over time. Panel A refers to the “Money Market”, defined as net lending to the financial sector. Panel B refers to the “Internal Capital Market”, which consists of net lending to affiliates. Panel C refers to “Securities holdings” (government bonds, other debt securities, money market fund shares and equities). All series are expressed in percentage points of total assets, and have been normalized by subtracting the pre-event average. The sample period is May 2019 - February 2020.

Figure 5: Example of actual and counterfactual allocations

Panel A: Example of actual pre- and post-tiering allocations



Panel B: Example of counterfactual post-tiering allocations



Panel A presents an example of actual pre-tiering and post-tiering allocation. In this example, the bank holds an equal share of asset X (e.g. money market loans) and asset Y (e.g. sovereign bonds) prior to tiering. After tiering, the bank increases its reserves by four units and finances this increase by selling three units of asset X and one unit of asset Y. Panel B presents examples of post-tiering counterfactual allocations. In the trade-off counterfactual allocation, the banks sells two units of asset X and two units of asset Y, i.e. it uses its pre-tiering allocation to decide how much asset X to sell relatively to Y. In the pecking order counterfactual, the bank sells four units of asset X, and none of asset Y. In the paper, we study the extent in which the actual change in allocation (here, selling three times as much asset X as Y) is significantly different from the trade-off counterfactual (here, selling as much asset X as asset Y), or significantly different from the pecking order counterfactual (here, selling asset X exclusively).

Table 1: Summary statistics

	$Treated = 1$ $N = 83$		$Treated = 0$ $N = 59$	
	Mean	St.Dev	Mean	St.Dev
$Total\ Assets$ (EUR billion)	69.26	128.56	107.52	202.75
$Cust.\ Loans$	49.3	21.1	48.3	25.7
$Fin.\ Loans$	18.8	22.0	15.6	17.8
$Reserves$	2.1	2.1	3.3	3.0
$Securities\ held$	19.0	12.1	19.0	17.0
$Cust.\ Deposits$	53.8	23.9	38.2	28.7
$Fin.\ Deposits$	20.3	17.2	25.7	24.0
$Debt\ securities\ issued$	4.5	8.1	13.4	20.1
$Book\ Equity$	9.4	5.6	10.8	13.6
$Unused\ allowance$	2.8	1.4	-0.4	0.8
$Money\ market$	-1.5	22.6	-10.1	30.3
$Internal\ capital\ market$	2.8	17.6	-5.3	19.3

All variables are as of September 2019 and are expressed as percentage points of total assets, unless stated otherwise. Variable definitions are as follows: $Treated_i$ is a dummy variable equal to one if bank i is a below-limit bank with unused allowance above the 25th percentile of all below-limit banks. Otherwise, $Treated_i$ is equal to 0 either if the unused allowance of bank i is below the 25th percentile of the distribution of the unused allowance of below-limit banks, and above the 75th percentile of the distribution of the unused allowance of above-limit banks. $Total\ Assets$ denotes total assets, expressed in billion EUR. $Cust.\ Loans$ ($Cust.\ Deposits$) denotes customer loans (deposits), defined as loans to (deposits from) households and non-financial corporations. $Securities\ held$ are holdings of securities, i.e. government bonds, other debt securities, money market fund shares and equities. $Fin.\ Loans$ ($Fin.\ Deposits$) denotes financial loans (deposits), defined as loans to (deposits from) the financial sector, excl. the ECB. $Reserves$ denotes reserves, defined as the sum of current account and deposit facility. $Debt\ securities\ issued$ are debt securities issued. $Unused\ allowance$ is the difference between the tiering limit and the bank's average holdings of reserves during the sixth reserve maintenance period, i.e. right before the implementation of tiering. $Money\ market$ is the difference between loans to and deposits from the financial sector. $Internal\ capital\ market$ is the difference between loans to and deposits from affiliates. The sample period is May 2019-Feb 2020.

Table 2: DiD regressions - Main results

	(1) Money Market	(2) Internal Cap. Mkt.	(3) Securities holdings
$Treated_i \times After_t$	-1.484***	-1.258***	-0.634**
	(0.550)	(0.354)	(0.287)
N	1,420	1,420	1,420
Within R-squared	0.0195	0.0297	0.0123

This Table reports coefficient estimates from the regression

$$Y_{i,t} = \alpha_i + \gamma_{c,t} + \delta(Treated_i \times After_t) + \epsilon_{i,t},$$

where the dependent variable $Y_{i,t}$ measures the balance sheet position of bank i at time t associated with a particular liquidity source, expressed as percentage points of total assets. $Treated_i$ is a dummy variable equal to one if bank i belongs to the treatment group, and zero if it belongs to the control group. $After_t$ is a dummy variable equal to one from October 2019 onwards, and zero otherwise, while α_i and $\gamma_{c,t}$ denote bank and country-time fixed effects. "Money Market" refers to net lending (loans minus deposits) to financial institutions. "Internal Cap. Mkt." denotes net lending to affiliates. "Securities holdings" refers to holdings of securities (debt securities, money market funds and equity). The sample period is May 2019 - February 2020. Standard errors clustered at the bank level are given in parentheses. Statistical significance at the 1%, 5% and 10% level is indicated by one, two, and three asterisks, respectively.

Table 3: DiD regressions - Separating lending and borrowing

	(1)	(2)	(3)	(4)	(5)	(6)
	Money Market		Internal Cap. Mkt.		Internal Cap. Mkt.	
	Loans	Deposits	Loans	Deposits	Loans	Deposits
$Treated_i \times After_t$	-0.435	1.049**	-0.629*	0.629**	-0.745**	0.366
	(0.434)	(0.409)	(0.366)	(0.299)	(0.330)	(0.234)
N	1,420	1,420	1,420	1,420	1,230	1,230
Within R-squared	0.00246	0.0152	0.00642	0.0109	0.00743	0.00328

This Table reports coefficient estimates from the regression

$$Y_{i,t} = \alpha_i + \gamma_{c,t} + \delta(Treated_i \times After_t) + \epsilon_{i,t},$$

where the dependent variable $Y_{i,t}$ measures the balance sheet position of bank i at time t associated with a particular liquidity source, expressed as percentage points of total assets. $Treated_i$ is a dummy variable equal to one if bank i belongs to the treatment group, and zero if it belongs to the control group. $After_t$ is a dummy variable equal to one from October 2019 onwards, and zero otherwise, while α_i and $\gamma_{c,t}$ denote bank and country-time fixed effects. "Money Market" loans (deposits) refers to loans to (deposits from) financial institutions. "Internal Cap. Mkt." loans (deposits) denotes loans to (deposits from) affiliates. The estimates in columns (5) and (6) are based on an alternative control group where affiliates of treated banks have been removed. The sample period is May 2019 - February 2020. Standard errors clustered at the bank level are given in parentheses. Statistical significance at the 1%, 5% and 10% level is indicated by one, two, and three asterisks, respectively.

Table 4: DiD regression results - Asset decomposition

	(1) Domestic govt. bonds	(2) Non-domestic EA govt. bonds	(3) Other securities
$Treated_i \times After_t$	-0.307***	-0.341	0.0138
	(0.105)	(0.226)	(0.272)
N	1,420	1,420	1,420
Within R-squared	0.0198	0.0179	6.48e-06

This Table reports coefficient estimates from the regression

$$Y_{i,t} = \alpha_i + \gamma_{c,t} + \delta(Treated_i \times After_t) + \epsilon_{i,t},$$

where the dependent variable $Y_{i,t}$ measures the balance sheet position of bank i at time t associated with a particular liquidity source, expressed as percentage points of total assets. $Treated_i$ is a dummy variable equal to one if bank i belongs to the treatment group, and zero if it belongs to the control group. $After_t$ is a dummy variable equal to one from October 2019 onwards, and zero otherwise, while α_i and $\gamma_{c,t}$ denote bank and country-time fixed effects. $Domestic\ govt.\ bonds$, $Non-domestic\ EA\ govt.\ bonds$ and $Other\ securities$ refer to holdings of domestic government bonds, non-domestic government bonds from the euro-area, and other securities (non-euro-area government bonds, money market fund shares, and equity), respectively. The sample period is May 2019 - February 2020. Standard errors clustered at the bank level are given in parentheses. Statistical significance at the 1%, 5% and 10% level is indicated by one, two, and three asterisks, respectively.

Table 5: Above-limit banks

	(1) Money market	(2) Internal Cap. Mkt.	(3) Securities holdings
Above limit$_i$	1.044**	0.196	-0.0386
	(0.500)	(0.422)	(0.202)
N	1,580	1,580	1,580
Within R-squared	0.00875	0.000414	0.000036

This Table reports coefficient estimates from the regression

$$Y_{i,t} = \alpha_i + \gamma_{c,t} + \delta(Above_i \times After_t) + \epsilon_{i,t},$$

where the dependent variable $Y_{i,t}$ measures the balance sheet position of bank i at time t associated with a particular liquidity source, expressed as percentage points of total assets. $Above_i$ is a dummy variable equal to one if bank i's tiering allowance is below the 75th percentile of all "above-limit" banks, and zero if it belongs to the control group. $After_t$ is a dummy variable equal to one from October 2019 onwards, and zero otherwise, while α_i and $\gamma_{c,t}$ denote bank and country-time fixed effects. "Money Market" refers to net lending (loans minus deposits) to financial institutions. "Internal Cap. Mkt." denotes net lending to affiliates. "Securities holdings" refers to holdings of securities (debt securities, money market funds and equity). The sample period is May 2019 - February 2020. Standard errors clustered at the bank level are given in parentheses. Statistical significance at the 1%, 5% and 10% level is indicated by one, two, and three asterisks, respectively.

Table 6: "Trade-off" vs. "Pecking order" view of liquidity

	(1)	(2)	(3)	(4)
	Post vs. "Trade-off"	Post vs. "Pecking order"		
		Money Market	Internal Cap. Mkt.	Sec. Holdings
Panel A: Assets				
Money market	-0.575	3.535	-1.481	-2.961
Internal Cap. Mkt.	-0.103	-0.674	1.949	-0.585
Sec. Holdings	0.678	-2.861	-0.468	3.546
N	90	90	90	90
F-statistic	1.381	21.361	27.214	6.917
p-value	0.257	<0.001	<0.001	0.002
Panel B: Liabilities				
Money market	-.219	-1.463	11.097	
Internal Cap. Mkt.	.219	1.463	-11.097	
N	90	90	90	
F-statistic	0.599	12.669	51.981	
p-value	0.441	0.001	<0.001	

Panel A presents the results of hypothesis tests of the form $\hat{\mathbf{a}}_{Post} - \hat{\mathbf{a}}_{Pre} = 0$ (column (1)) and $\hat{\mathbf{a}}_{Post} - \hat{\mathbf{a}}_{C} = 0$ (columns (2)-(4)), where the vectors $\hat{\mathbf{a}}_{Pre}$, $\hat{\mathbf{a}}_{Post}$, and $\hat{\mathbf{a}}_{C}$ denote treated banks' average allocation on the asset side of their balance sheet during the pre-event window ("Trade-off" counterfactual), post-event window, or for a "Pecking order" counterfactual simulation, respectively. Panel B provides similar hypothesis tests for the liability side, based on the vectors $\hat{\mathbf{l}}_{Pre}$, $\hat{\mathbf{l}}_{Post}$, and $\hat{\mathbf{l}}_{C}$. Details are provided in Section 4.2. *Money Market* refers to loans to (deposits from) financial institutions. *Internal Cap. Mkt.* denotes loans to (deposits from) affiliates, while *Sec. Holdings* denotes banks' securities holdings. Inference is based on Hotelling's t-squared test. The sample period is May 2019 - February 2020.

Table 7: "Trade-off" vs. "Pecking order" view of liquidity - Adjustment for liability-side constraints

	(1)	(2)	(3)
	Post vs. "Trade-off"	Post vs. "Pecking order"	
		Money Market	Internal Cap. Mkt.
Money market	-.610	-1.960	5.296
Internal Cap. Mkt.	1.960	0.020	-5.296
N	62	62	62
F-statistic	1.858	11.746	14.315
p-value	0.178	0.001	<0.001

This table presents the results of hypothesis tests of the form $\hat{\mathbf{l}}_{Post} - \hat{\mathbf{l}}_{Pre} = 0$ (column (1)) and $\hat{\mathbf{l}}_{Post} - \hat{\mathbf{l}}_{C} = 0$ (columns (2)-(3)), where the vectors $\hat{\mathbf{l}}_{Pre}$, $\hat{\mathbf{l}}_{Post}$, and $\hat{\mathbf{l}}_{C}$ denote treated banks' average allocation on the liability side of their balance sheet during the pre-event window ("Trade-off" counterfactual), post-event window, or for a "Pecking order" counterfactual simulation, respectively. In the counterfactual simulation, borrowing from affiliates is limited to the amount of reserves that exceed the aggregate tiering allowance at the group level. Details are provided in Section 4.2. *Money Market* refers to loans to (deposits from) financial institutions, while *Internal Cap. Mkt.* denotes loans to (deposits from) affiliates. Inference is based on Hotelling's t-squared test. The sample period is May 2019 - February 2020.

Table 8: Determinants of the residuals of the "Trade-off" analysis

Dependent variable: Residuals from trade-off analysis			
	(1)	(2)	(3)
Panel A: Assets			
Deposit ratio	-0.0284**		-0.0491***
	(0.0136)		(0.0183)
Loan to security ratio (log)	0.564**		0.893***
	(0.240)		(0.269)
N	82	82	82
R-squared	0.0718	0.1906	0.3200
Country dummies	No	Yes	Yes
Panel B: Liabilities			
Deposit ratio	-0.00179		-0.00477
	(0.0121)		(0.0119)
Loan to security ratio (log)	0.349*		0.439**
	(0.180)		(0.217)
N	82	82	82
R-squared	0.0566	0.2546	0.3229
Country dummies	No	Yes	Yes

On the asset side, the dependent variable is computed as the sum of the absolute value of the first two components of $\hat{\mathbf{a}}_{Post} - \hat{\mathbf{a}}_{Pre}$, where the vectors $\hat{\mathbf{a}}_{Pre}$ and $\hat{\mathbf{a}}_{Post}$ denote treated banks' average allocation on the asset side of their balance sheet during the pre-event window ("Trade-off" counterfactual) and post-event window, respectively. On the liability side, the dependent variable is computed as the absolute value of the first components of $\hat{\mathbf{l}}_{Post} - \hat{\mathbf{l}}_{Pre}$. Details are provided in Section 4.2. *Depositratio* is equal to the ratio of customer deposit to asset holdings. *Loantosecurityratio* is the ratio of customer loan to security holdings. The sample period is May 2019 - February 2020.

ONLINE APPENDIX

Table A.1: DiD regressions - Continuous treatment

	(1) Money market	(2) Internal Capital Market	(3) Securities holdings
$Unused\ allowance_i \times After_t$	-0.00492***	-0.00297***	-0.00212***
	(0.00145)	(0.00106)	(0.000737)
N	1,420	1,420	1,420
Within R-squared	0.0263	0.0203	0.0168

This Table reports coefficient estimates from the regression

$$Y_{i,t} = \alpha_i + \gamma_{c,t} + \delta(Unused\ Allowance_i \times After_t) + \epsilon_{i,t},$$

where the dependent variable $Y_{i,t}$ measures the balance sheet position of bank i at time t associated with a particular liquidity source, expressed as percentage points of total assets. $Unused\ Allowance_i$ is equal to the difference between the tiering limit and the bank i's average reserve holdings over the sixth maintenance period (i.e. right before the implementation of tiering). It is set to zero if the difference is negative. $After_t$ is a dummy variable equal to one from October 2019 onwards, and zero otherwise, while α_i and $\gamma_{c,t}$ denote bank and country-time fixed effects. "Money Market" refers to net lending (loans minus deposits) to financial institutions. "Internal Cap. Mkt." denotes net lending to affiliates. "Securities holdings" refers to holdings of securities (debt securities, money market funds and equity). The sample period is May 2019 - February 2020. Standard errors clustered at the bank level are given in parentheses. Statistical significance at the 1%, 5% and 10% level is indicated by one, two, and three asterisks, respectively.

Table A.2: DiD regressions - Placebo

	(1)	(2)	(3)	(4)	(5)	(6)
	Money market		Internal Capital Market		Securities holdings	
	Placebo 1	Placebo 2	Placebo 1	Placebo 2	Placebo 1	Placebo 2
$Treated_i \times After\ Placebo_t$	-0.561	-0.398	-0.147	0.499	0.0587	0.0946
	(0.434)	(0.549)	(0.356)	(0.396)	(0.170)	(0.269)
N	568	1,390	568	1,390	568	1,390
Within R-squared	0.00810	0.00094	0.00766	0.00339	0.00043	0.00030

This Table reports coefficient estimates from the regression

$$Y_{i,t} = \alpha_i + \gamma_{c,t} + \delta(Treated_i \times After\ Placebo_t) + \epsilon_{i,t},$$

where the dependent variable $Y_{i,t}$ measures the balance sheet position of bank i at time t associated with a particular liquidity source, expressed as percentage points of total assets. $Treated_i$ is a dummy variable equal to one if bank i belongs to the treatment group, and zero if it belongs to the control group. α_i and $\gamma_{c,t}$ denote bank and country-time fixed effects. In column 1, 3, 5 (column 2, 4, 6), $After\ Placebo_t$ is a dummy variables that is equal to zero from May 2019 to June 2019 (from May 2017 to September 2017) and is equal to one from July 2019 to August 2019 (from October 2017 to February 2018). “Money Market” refers to net lending (loans minus deposits) to financial institutions. “Internal Cap. Mkt.” denotes net lending to affiliates. “Securities holdings” refers to holdings of securities (debt securities, money market funds and equity). The sample period is May 2019 - February 2020. Standard errors clustered at the bank level are given in parentheses. Statistical significance at the 1%, 5% and 10% level is indicated by one, two, and three asterisks, respectively.

Table A.3: DiD regression results - Other assets and liabilities

	(1) Customer loans	(2) Customer deposits	(3) Debt securities issued	(4) Equity
Constant	48.89***	47.73***	8.253***	10.01***
	(0.0938)	(0.0783)	(0.0536)	(0.0456)
$Treated_i \times After_t$	-0.422	-1.053***	-0.226	-0.108
	(0.321)	(0.268)	(0.183)	(0.156)
N	1,420	1,420	1,420	1,420
Within R-squared	0.00444	0.0311	0.00619	0.00171

This Table reports coefficient estimates from the regression

$$Y_{i,t} = \alpha_i + \gamma_{c,t} + \delta(Treated_i \times After_t) + \epsilon_{i,t},$$

where the dependent variable $Y_{i,t}$ measures the balance sheet position of bank i at time t associated with a particular liquidity source, expressed as percentage points of total assets. $Treated_i$ is a dummy variable equal to one if bank i belongs to the treatment group, and zero if it belongs to the control group. $After_t$ is a dummy variable equal to one from October 2019 onwards, and zero otherwise, while α_i and $\gamma_{c,t}$ denote bank and country-time fixed effects. "Customer loans" ("customer deposits"), defined as loan to (deposits by) households and non-financial corporations. "Debt securities issued" is the bank's debt liability. "Equity" is total equity as reported on the balance sheet. The sample period is May 2019 - February 2020. Standard errors clustered at the bank level are given in parentheses. Statistical significance at the 1%, 5% and 10% level is indicated by one, two, and three asterisks, respectively.

Table A.4: Triple-diff regressions

TE = Treatment effect	(1)	(2)	(3)	(4)	(5)	(6)
TI = Triple interaction	Money Market		Internal Cap. Mkt.		Security holdings	
	TE	TI	TE	TI	TE	TI
$Vulnerable$	-1.778***	0.949	-1.600***	1.104*	-0.723**	0.288
	(0.531)	(1.430)	(0.467)	(0.647)	(0.303)	(0.698)
$Govyield$	-1.481***	-0.0528	-1.272***	0.250	-0.644**	0.190
	(0.532)	(0.789)	(0.355)	(0.277)	(0.274)	(0.408)
$Size$	-1.523***	0.636	-1.306***	0.189	-0.606**	-0.115
	(0.567)	(0.572)	(0.345)	(0.306)	(0.303)	(0.273)
$Leverageratio$	-1.710***	-2.698**	-0.763**	1.298*	-0.699*	0.0915
	(0.619)	(1.173)	(0.322)	(0.772)	(0.359)	(0.859)
$Networkdegree$	-1.441***	0.613	-1.236***	0.0768	-0.653**	0.0669
	(0.522)	(0.528)	(0.341)	(0.389)	(0.271)	(0.267)

This Table reports coefficient estimates from the regression

$$Y_{i,t} = \alpha_i + \gamma_{c,t} + \delta(Treated_i \times After_t) + \zeta(Treated_i \times After_t \times X_i) + \epsilon_{i,t},$$

where the dependent variable $Y_{i,t}$ measures the balance sheet position of bank i at time t associated with a particular liquidity source, expressed as percentage points of total assets. $Treated_i$ is a dummy variable equal to one if bank i belongs to the treatment group, and zero if it belongs to the control group. $After_t$ is a dummy variable equal to one from October 2019 onwards, and zero otherwise. X_i is a bank- or country-level characteristic, while α_i and $\gamma_{c,t}$ denote bank and country-time fixed effects. "Money Market" loans (deposits) refers to loans to (deposits from) financial institutions. "Internal Cap. Mkt." loans (deposits) denotes loans to (deposits from) affiliates. $Vulnerable_i$ is a dummy variable equal to one if the average yield over the sample on the sovereign debt issued by bank i's country is above the median of that of the country sample, 0 otherwise. In absence of yield data, the value for Estonia is equal to one. $Size_i$, $Leverageratio_i$ and $Networkdegree_i$ are the standardized average size, regulatory leverage ratio and network centrality of bank i, respectively. "TE" and "TD" denote the treatment effect and the triple interaction, respectively. The sample period is May 2019 - February 2020. Standard errors clustered at the bank level are given in parentheses. Statistical significance at the 1%, 5% and 10% level is indicated by one, two, and three asterisks, respectively.

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