EUROPEAN CENTRAL BANK
EUROSYSTEM

Working Paper Series

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Liquidity dependencies in the euro area

No 3056

Abstract

This study investigates to what extent the significant liquidity injections by the ECB over the past 15 years may have created a dependency by banks on central bank liquidity itself. Following Acharya et al. (2024), I examine whether the ECB's liquidity provision changed banks' incentives to increase liquid deposits, potentially heightening their susceptibility to liquidity shocks. Using both aggregate and bank-level data, I find that euro area banks tend to increase demand deposits and decrease time deposits with their holdings of excess reserves over the liquidity expansion phase and do not revert when aggregate liquidity starts to shrink. However, this is contained to specific periods, when interest rates were low and stable. The differences relative to the US could be related to distinct sources of liquidity and regulatory frameworks governing liquidity.

JEL-Classification: E5, G21.

Keywords: Monetary policy, central bank liquidity, deposits, euro area.

Non-technical summary

This paper investigates whether increased central bank liquidity affects banks' willingness to hold liquid deposits in a way that may heighten their exposure to liquidity shocks. This is a relevant question for policy makers, as it relates to the demand for central bank liquidity and provides insights into potential side effects of balance sheet policies. Drawing from the work by Acharya et al. (2024) for the US, this paper follows their research question for the euro area, discussing also the differences between the two regions.

The main finding is that, as euro area banks increased their excess reserves, they also increased their holdings of liquid deposits, especially during the period when the ECB expanded its balance sheet via the APP. Simultaneously, banks decreased holdings of time deposits with excess reserves. These trends did not reverse when the ECB began reducing its balance sheet. The build-up of liquidity dependencies was not evident during the pandemic when the ECB also purchased large amounts of assets through the PEPP. Thus, it may be more prevalent during periods of low and stable interest rates, akin to the risk-taking channel. The results point that the increase in liquidity exposure was driven primarily by more fragile banks, which could benefit more from deposits as a cheaper funding source. The milder results for the euro area relative to the US could be related to the source of liquidity provision. Indeed, it is found that the build-up of liquidity dependencies seems to be more related to outright purchases of assets than to refinancing operations. The study employs a multifaceted methodological approach. In the first part, the analysis relies on aggregate time series. This initial phase examines the relationship between liquidity provision and deposit holdings by banks, providing a descriptive understanding of the dynamics. The second phase makes use of the heterogeneity of banks' behavior in the euro area to better grasp the response of banks to the expansion of the ECB balance sheet. In this way, the analysis incorporates individual bank-level data using an instrumental variable (IV) approach to control for endogeneity, effectively identifying the influence of reserves on deposit supply.

The findings have significant policy implications. In the short term, it is relevant for the Eurosystem to better understand the demand for reserves, as the balance sheet continues to reduce. In the medium term, if banks' preferences for liquidity may have indeed increased relative to the past when aggregate liquidity was balanced, this may pose greater risks to the banking sector when faced with liquidity shocks. The market stress in the US in 2019 is one example of such vulnerabilities. In the long-term, central banks may need to take into account the side effects of balance sheet policies discussed in the paper when designing these policies in the future in case of need.

1 Introduction

In the past 15 years, central banks have undertaken unprecedented measures to inject liquidity into the banking system, both in terms of magnitude and pace. However, the broader and longer-term effects of these liquidity injections, which persisted for approximately a decade in major advanced economies, are still not fully understood. As central banks transitioned away from the ultra-low interest rate and high liquidity environment, uncertainties arose regarding the consequences of this 'normalization' process. One particular concern is the possibility of hysteresis effects, where the supply of reserves may have created its own demand. This phenomenon could be attributed to banks becoming accustomed to operating in a high liquidity environment, potentially leading to a temporary increase in their demand for reserves as they adapt to the new environment.

Understanding the dynamic effects of liquidity supply and demand is crucial for central bankers. From an operational point of view, central banks (at least in major advanced economies) need to forecast a portion of the demand for liquidity to effectively manage interest rates, whether operating in a floor, corridor, or intermediate system. When working under ample liquidity conditions, the central bank needs at least to supply the minimum level of liquidity that saturates the market. If demand for liquidity is higher, the point where interest rates can start showing some volatility may be reached for higher levels of primary liquidity.

Additionally, central bankers must consider the side effects of liquidity provision from a financial stability perspective. If banks' incentives to hold liquid claims increase with primary liquidity provision, it could have implications for financial stability and thus could be taken into account when designing balance sheet policies.

This paper aims to investigate the existence of liquidity dependencies in the euro area. Drawing on the methodology of Acharya et al. (2024) for the United States, this study examines how the European Central Bank's (ECB) liquidity provision may have influenced commercial banks' incentives to supply liquid deposits, potentially increasing their exposure to liquidity shocks and the likelihood of central bank interventions becoming necessary to contain contagion across the banking system. It thus represents the first endeavor to undertake such an analysis in this region and it offers novelty by delving into the source of liquidity provision. Firstly, I conduct a time series aggregate analysis, scrutinizing the relationship between liquidity provision and deposit holdings by banks. This initial phase serves mostly to provide a descriptive understanding and motivation for the remaining investigation. Subsequently, I delve deeper into the analysis by incorporating individual bank-level data. Here, I employ an instrumental variable (IV) approach to effectively control for endogeneity, thereby discerning the influence of reserves on deposit supply. This second phase aims to unravel the nuanced responses of banks' deposit supply to liquidity provision.

If the euro area were to mirror the results observed in the United States, one might anticipate a parallel increase in banks' liquidity claims. However, it is important to acknowledge that different contextual factors may yield divergent outcomes. Notably, disparities in the sources of liquidity provision and the regulatory environment between the two regions could potentially justify disparate results. The banking systems of the two regions are also different, with, for example, a more concentrated market for deposits in the US.

The empirical findings suggest that banks in the euro area increased their exposure to liquid deposits with the expansion of central bank liquidity, with developments showing asymmetry over the policy cycle. The increase in aggregate deposits in large part reflects the mechanical effect of the increase in excess liquidity. However, evidence supports an intended increase in the supply of demand deposits by banks during some periods of increasing excess liquidity. Notably, during the period from 2015 to 2017, when the ECB expanded liquidity via mostly outright purchases under the Asset Purchase Programme (APP), banks increased their supply of demand deposits, at the same time that they decreased the supply of time deposits. The shift in demand deposits was driven by the increase in banks' non-borrowed reserves, with the shift in time deposits coming from borrowed reserves. However, this trend was not observed during the pandemic period, when the ECB also purchased large amounts of assets under the Pandemic Emergency Purchase Programme (PEPP). One hypothesis is that increased demand for deposits from households and firms during the pandemic, due to the sudden and large halt in expenditure opportunities, may have constrained banks' ability to increase further the supply of deposits due to balance sheet constraints. Another hypothesis relates to the macroeconomic context, with very low and stable interest rates and limited macroeconomic risk, which may have incentivized banks to take on more risk, similar to the risk-taking channel. When excess liquidity starts to shrink, there is not a reversal of the supply of demand deposits. Banks' behavior seems to be different according to the source of excess liquidity. When excess reserves come mostly from temporary refinancing operations, there is no impact from excess reserves on banks' supply of demand but banks decrease time deposits. When reserves come mostly from asset purchases, demand deposits increase substantially. Thus, in line with the results for the US, large-scale asset purchases seem to be the main driver of changes in demand for liquidity due to its own supply by the central bank, at least under a sluggish macroeconomic context.

Theoretical frameworks, such as that provided by Acharya and Rajan (2024), offer insights into the mechanisms driving these effects. Banks may finance excess reserves with demandable deposits, as short-term or demandable debt is more advantageous than long-term financing, due to, for example, higher cost of capital or asset and liability matching. If the economy gets liquidity stressed, affecting some banks in a disproportionate manner, depositors will try to withdraw their deposits, heightening the liquidity stress. Banks perceive this possibility and, thus prefer to hoard liquidity which gets attached a convenience yield. These banks want to be perceived as safe and avoid a run on their deposits. Although aggregate liquidity would be sufficient to cope with the liquidity shock, the hoarding of liquidity by some banks exacerbates the liquidity needs. The liquidity stress can be visible in sudden spikes and tensions in short-term money markets, as those observed in the US in September 2019 and March 2020. Acharya et al. (2024) provide empirical evidence supporting this mechanism for the US.

In the Acharya and Rajan (2024) framework, it is also relevant that the liquidity expansion intended by the central bank needs to go over the banking system and involve non-banks that do not have access to the central bank. This has occurred in the liquidity expansion by the Fed, involving purchases of assets that were held by non-banks. However, there is evidence of the involvement of the non-bank sector in the euro area, as the ultimate owners of the asset purchased were non-banks (Corradin et al., 2020). The large demand for liquidity storage in the money market with euro area banks, especially from non-banks, is also testimony of banks intermediating excess liquidity between non-banks and the central bank.

The effects of central bank liquidity on bank reserves is relevant for policy as it can affect the transmission of monetary policy. Different funding structure of the banks interacts with funding conditions and costs that banks face that then get transmitted to the rest of the economy. Usually funding through deposits is less expensive than market funding, which can affect the lending conditions. Drechsler et al. (2017) show that bank deposits affect policy transmission, especially when coupled with market power in the deposit market. When the market is more concentrated, banks impose a larger markup on deposit rates, leading to fewer deposits than in more competitive markets. As deposits are a stable source of funding for banks, it will impact bank lending, exacerbating the contractionary impact of a policy tightening if one would ignore this channel. Another strand in the literature that has arisen recently relates more directly to bank reserves and lending activity. Diamond et al. (2024) argue in favor of a reserve supply channel, where, for a bank, reserves and loans are seen as substitutes rather than complements. As banks are forced to hold reserves, coming from the expansion of liquidity through asset purchases, and given that banks are subject to balance sheet constraints (the leverage ratio, for instance), they will limit the growth of their balance sheet by cutting on the loan supply. Thus, a quantitative easing policy can have a contractionary impact on the economy. Altavilla et al. (2023) discuss the operational framework for implementing monetary policy and find that in the euro area non-borrowed reserves, ie, those coming mostly from large-scale asset purchases, contributed to bank credit expansion.

The impact of reserves on banks' liquidity exposure can increase liquidity risks of the financial system (Acharya et al., 2024). It is clear, especially after the last 15 years, that risks to financial stability can impair the monetary policy transmission mechanism. The case presented in Acharya et al. (2020) shows how this interaction may be relevant. The increase in central bank liquidity in response to a financial crisis reduces deposit spreads for all banks. However, they only find evidence of a reduction in loan spreads for high risk banks. These are the banks with higher agency costs that see an easing in their constraints with the full allotment policy. In this case, the banks' balance sheets remain generally weak and monetary policy could be 'pushing on a string'. Other studies have discussed the side effects of the central banks' liquidity expansion. Drechsler et al. (2016) and Crosignani et al. (2020) argue that euro area banks increased risk-taking following liquidity expansion via refinancing operations with fixed-rate full allotment during the sovereign debt crisis. Drechsler et al. (2016) defend that this provides support to alternative lender-of-last-resort theories that highlight moral hazard and risk-taking behavior by banks.

Overall, the results found in the paper suggest that euro area banks have built liquidity dependencies, but these seem weaker than in the US and focused on one specific period. This can be due to the different sources of liquidity, as discussed above. It can also be due to the different implementation of liquidity regulation in the two areas. The fact that some smaller banks are exempt from complying with liquidity coverage ratio (LCR) requirements, may have created greater incentives for these banks to increase their liquidity risk.[1] Sundaresan and Xiao (2024) show that indeed non-LCR banks took more liquidity risk, while LCR banks approximated to their optimal coverage ratio, which could contribute to explain the difference between the US and the EA. Their analysis builds on empirical analysis but also from a theoretical model, that concludes that LCR is a second best, because it works as an implicit tax on banks. Acharya et al. (2024) also show that it is mostly small banks, those not subject to LCR requirements, that are responsible for the ratching-up of demandable claims to potential liquidity. This paper does not test empirically the hypothesis related to the different regulatory environments due to the lack of data available on regulatory compliance.

2 Data

This study uses aggregate time series data and bank-level data for the cross-section analysis, described more in detail in the following subsections.

2.1 Aggregate time series

Most aggregate data is drawn from the ECB Statistical Data Warehouse (SDW). Deposits data are from the Balance Sheet Items (BSI) statistics and consist of outstanding amounts at the end of the period, held on euro area MFIs, all currencies combined. The main series of interest are the demand deposits from the non-financial private sector, which are considered to be the deposits that are part of the monetary aggregate M3. Time deposits are set as the difference between total deposit liabilities held by the euro area non-financial private sector and previously defined demand deposits. Euro area excess reserves are taken from Eurosystem liquidity management data and are

[1] The March 2023 market turmoil may reflect these changed incentives. Some small banks in the US were not subject to LCR requirements, including the SVB that failed at the time.

defined as bank reserves (including those held under the standing deposit facility). I split excess reserves between borrowed reserves, ie, the liquidity provided by temporary refinancing operations (MRO, LTRO, and TLTRO)[2], and non-borrowed reserves, given by the remaining excess reserves, which main driver corresponds to liquidity provided via outright purchases of debt securities.

The pricing of reserves is assessed with the €STR spread to the Deposit Facility Rate (DFR), one of the key policy rates set by the ECB. With ample supply reserves, the DFR works as the anchor rate for money market rates (Schnabel, 2023). €STR is expanded backwards with a constant -8.5 bp spread relative to EONIA for a longer time series.[3]

Data on households' financial assets and the yield curve slope is also used to control for the supply side of deposits from customers (Lopez-Salido and Vissing-Jorgensen, 2023). Households' financial assets are taken from financial accounts while the yield curve slope is set as the spread between 10-year and 1-year maturity spot rates on all euro area issuers' government bonds.

2.2 Bank-level data

Bank-level data replicates to the extent possible the aggregate data. Both excess reserves and deposits data at the bank level follow the same definitions as the aggregate level data. Deposits data comes from the individual Balance Sheet Items (IBSI) statistics, which includes balance sheet data at the bank level for a sample of around 300 banks representing around 2/3 of euro area MFI total assets and demand deposits. For the regression analysis, I use bank-level controls (total assets and balance sheet capital ratio) that are also taken from the IBSI dataset. Data on deposit rates at the bank level is taken from the individual MFI interest rate statistics, that has the same coverage as IBSI. Table A.1 shows some summary statistics for the main variables of interest at the bank level.[4] The average bank has EUR 70 bn of total assets, EUR 20 bn of which are financed with demand deposits and EUR 5 bn with time deposits, for the total period. However, there is a significant heterogeneity over time and across banks. The balance sheet increases over time, coming from the large increase in reserves with the increase in deposits as a counterpart.

3 Empirical analysis

3.1 Analysis at the aggregate level

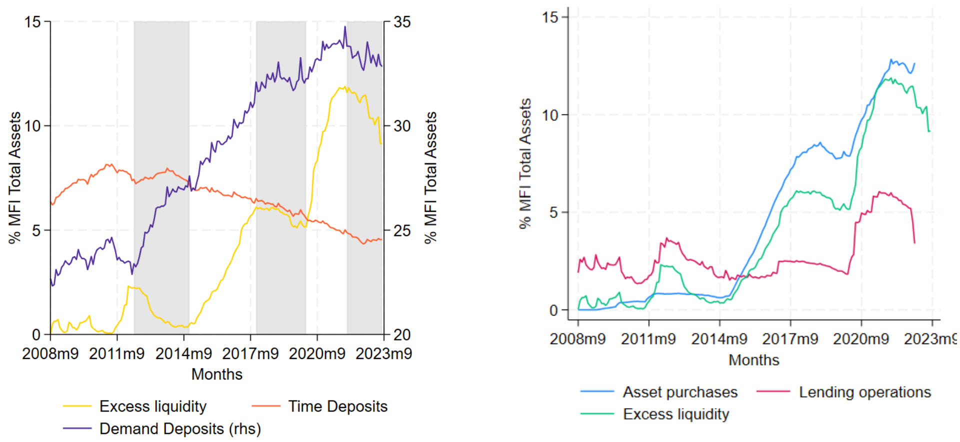
Figure 1a plots the evolution of euro area excess liquidity and deposits as a share of total assets of the banking system. The shaded areas represent periods when excess liquidity was kept stable or reduced as a result of policy decisions. The period under analysis is split into 6 periods, alternating between increasing liquidity and stable or falling liquidity. The three periods of expanding excess liquidity go from (1) September 2008 to June 2012, (2) January 2015 to December 2017, and (3) May 2020 to December 2021. The three periods of decreasing excess liquidity go from (1) July 2012 to December 2014, (2) January 2018 to April 2020, and (3) from January 2022 onwards (until September 2023). The main instrument used by the ECB to expand liquidity, refinancing operations or asset purchases, differed across time (Figure 1b).

The first period goes from September 2008 to June 2012, characterized by the large expansion of liquidity provision following the onset of the global financial crisis (GFC). In response to the GFC, excess liquidity started to build up mostly via regular refinancing operations. In December 2011 and March 2012, the ECB injected its largest amount ever until then via very long-term

[2]Main Refinancing Operations, Long-Term Refinancing Operations, and Targeted Long-Term Refinancing Operations, see https://www.ecb.europa.eu/mopo/implement/omo/html/index.en.html.

[3]See https://www.ecb.europa.eu/press/pr/date/2019/html/ecb.pr190531 a3788de8f8.en.html

[4]From December 2018 onwards, the sample of IBSI banks was enlarged to more than 1000 institutions, covering over 80% of euro area MFI total assets and demand deposits. The regression analysis is overall consistent whether the large or the small sample is included. Results shown in the paper report to the large sample.



(a) Excess liquidity and deposits as a percentage of MFI total assets.

(b) Excess liquidity, monetary policy portfolio, and Eurosystem refinancing operations as a percentage of MFI total assets.

Figure 1

refinancing operations (VLTRO), amounting to an allotment amount of EUR 1019 billion. Banks had the opportunity of early repayment to the Eurosystem from January 2013 onwards. Excess liquidity stabilized from mid-2012 on, so the first period of stable or falling liquidity goes from July 2012 to December 2014, corresponding to the first shaded area in Figure 1a. The second period of expanding excess liquidity goes from January 2015 to December 2017, characterized by the purchases of securities under the Asset Purchase Programme (APP). The pace of net purchases was reduced in 2018 and stopped between January and October 2019. Excess liquidity stabilized close to EUR 1.9 trillion since late 2017 and fell slightly until the start of the pandemic. This corresponds to the second period of stable/falling liquidity ranging between January 2018 and April 2020. The third period of liquidity expansion starts in May 2020 and ends in December 2021. From March 2020 onwards, the ECB expanded strongly its balance sheet in response to the pandemic shock through securities purchases under the APP, the new Pandemic Emergency Purchase Programme (PEPP), and liquidity providing operations among which a new series of Targeted Longer-Term Refinancing Operations (TLTRO). The policy normalization began in December 2021 with the announcement of the phasing out of net purchases under PEPP and APP, which actually ended in March 2022 under PEPP and in July 2022 under APP. Therefore, the third period of stable and then reducing excess liquidity starts in January 2022. Despite the policy normalization during 2022, excess liquidity reached a maximum level of over EUR 4.6 trillion in the autumn of 2022, due to the evolution of exogenous factors that pressured down the demand for liquidity.

Figure 1a shows a strong increasing trend in demand deposits from the non-financial private sector, almost parallel to the evolution of excess liquidity. In part, this reflects the balance sheet identity where the counterpart for Eurosystem liquidity provision is an increase in overall deposits. When the central bank provides liquidity to banks, this ends up immediately in deposits from banks into the central bank.[5] The banks can use this liquidity to lend, but at the moment of its creation, it still ends up in a deposit from the borrower into one bank. Central bank liquidity takes time to get absorbed by agents outside the banking system until it corresponds to actual demand for liquidity, such as banknotes, necessary for economic activity.

The increase in deposits seems to be particularly focused on demand deposits. Time deposits over total assets kept an overall decreasing trend over the last 15 years, which seemed to have been interrupted more recently. Demand deposits can be easily withdrawn, thus increasing banks'

[5]The exception is the case when the central bank buys assets issued by banks, for instance, bank bonds, which would make it equivalent to an asset swap with no impact on deposits.

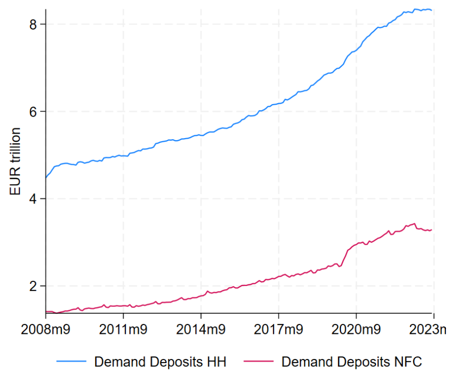


Figure 2: Evolution of demand deposits in the euro area.

exposure to liquidity risk. Such increase come from both deposits from households and from non-financial corporations (Figure 2). These deposits can be easily redeemed, although a part of them can be assumed stable, namely insured deposits, as considered under the Liquidity Coverage Ratio (LCR) regulation. If the bank faces a liquidity shock, it can face a run to deposits, especially in deposits with a greater risk of flightiness such as those from firms (Blickle et al., 2024).

The continued increase in demand deposits is particularly acute in the first period of liquidity reduction (Figure 1a). This period coincided with the follow-up of the sovereign debt crisis when several euro area countries' banking systems were under stress and a process of restructuring and strengthening of balance sheet. Therefore, the increase in deposits could reflect a move towards more stable funding sources by the banks, not related to monetary policy but as a result of regulatory and financial stability policies. However, such a shift could have occurred through either demand or time deposits, which has different implications for financial stability. Supply factors could also play a role, as under a financial crisis investors may prefer safer and more liquid investments such as demand deposits backed up by deposit guarantee funds. Finally, the very low interest rate environment may have also contributed to a preference from investors towards short-term and liquid deposits.

During the second period of stable or slightly decreasing excess liquidity, around 2018-2019, one can also observe a continued increase in demand deposits. During this period, demand deposits went from 5 times to 6 times excess liquidity. The banking sector was more robust at the time but a low and stable interest rate environment may have continued to weigh in significantly on the investors' preference for deposits, especially short-term deposits.

Finally, the third period shows a different evolution, with a fall in demand deposits as excess liquidity decreases. This period coincides with the normalization of monetary policy and a return of the policy interest rate to positive levels. At the same time, time deposits increased slightly, which can be also related to the higher level of interest rates that motivated a shift in the demand by investors from short-term deposits to longer maturities. The aggregate evolution depicted in the charts seems already to suggest that other factors may be more relevant in driving the evolution of demand deposits in the euro area, such as those related to the adjustment following the financial crisis and those related to the supply of deposits from households and firms.

The relationship between aggregate deposits and excess liquidity is assessed in a more formal way, by means of an econometric regression similar to Acharya et al. (2024), where changes in the time-series of aggregate excess liquidity explain changes in the time-series of aggregate deposits in the euro area:

$$\Delta D_t = \alpha \Delta EL_t + \beta EL_{t-12} + \epsilon_t \quad (1)$$

where EL_t is the excess liquidity of the Eurosystem and can be defined in natural logarithms, in

	$\Delta Ln(TotDepo)$		$\Delta Ln(DemandDepo)$		$\Delta Ln(TimeDepo)$		$\Delta Ln(DemandDepoHH)$		$\Delta Ln(DemandDepoNFC)$		$\Delta Ln(ExternalDepo)$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$\Delta Ln(EL)$	0.023***	0.017***	0.009**	0.004	-0.012	-0.008	0.011***	0.007***	0.004	-0.001	0.026**	0.015
	(0.005)	(0.005)	(0.004)	(0.003)	(0.009)	(0.010)	(0.003)	(0.003)	(0.005)	(0.003)	(0.011)	(0.011)
$Ln(EL_{t-12})$	0.014***	0.006	0.005	-0.001	-0.019***	-0.015*	0.005**	0.001	0.009*	0.002	0.029***	0.014
	(0.005)	(0.005)	(0.003)	(0.003)	(0.007)	(0.008)	(0.003)	(0.003)	(0.005)	(0.002)	(0.008)	(0.011)
Slope		-0.020*		-0.016**		0.011		-0.012*		-0.018		-0.037*
		(0.012)		(0.008)		(0.016)		(0.007)		(0.012)		(0.022)
Constant	-0.169***	-0.038	-0.027	0.083*	0.242**	0.165	-0.028	0.050	-0.055	0.063	-0.380***	-0.129
	(0.062)	(0.079)	(0.041)	(0.048)	(0.098)	(0.134)	(0.032)	(0.051)	(0.058)	(0.039)	(0.118)	(0.165)
Observations	180	180	180	180	180	180	180	180	180	180	180	180

Note: Results from estimation of equation (1), for each dependent variable shown in columns. Variables are defined in natural logarithms. Δ variables are defined as 12-month changes. Estimation period: September 2008 to August 2023. Standard errors in parentheses adjusted for autocorrelation in the residuals up to 12 months. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1: Relationship between aggregate deposits and excess liquidity, measured in logarithms (elasticity).

	$\Delta TotDepo$		$\Delta DemandDepo$		$\Delta TimeDepo$		$\Delta DemandDepoHH$		$\Delta DemandDepoNFC$		$\Delta ExternalDepo$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
ΔEL_t	1.099***	1.032***	0.309***	0.275***	-0.040	-0.015	0.160***	0.144***	0.119***	0.104***	0.134*	0.095
	(0.174)	(0.204)	(0.068)	(0.074)	(0.029)	(0.030)	(0.031)	(0.035)	(0.034)	(0.031)	(0.072)	(0.072)
EL_{t-12}	0.209**	0.129	0.069**	0.029	-0.021	0.009	0.042**	0.022	0.025**	0.008	0.098***	0.052
	(0.085)	(0.114)	(0.030)	(0.030)	(0.015)	(0.014)	(0.016)	(0.015)	(0.010)	(0.010)	(0.025)	(0.042)
Slope		-204040		-101772*		76045**		-49097		-45070**		-117158
		(180158)		(57645)		(33641)		(32378)		(22367)		(71915)
Constant	-17179	424164	257763***	477899***	24021	-140466**	168545***	274742***	66442***	163929***	-155096**	98319
	(159803)	(468789)	(45346)	(133830)	(50008)	(68788)	(31871)	(74030)	(17070)	(49436)	(71189)	(158940)
Observations	180	180	180	180	180	180	180	180	180	180	180	180

Note: Results from estimation of equation (1), for each dependent variable shown in columns. Variables are defined in euro. Δ variables are defined as 12-month changes. Estimation period: September 2008 to August 2023. Standard errors in parentheses adjusted for autocorrelation in the residuals up to 12 months. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2: Relationship between aggregate deposits and excess liquidity, measured in euros.

absolute values, or in ratio over banks' total assets. The dependent variable D_t will be, at each turn, the different types of deposits (demand, time, and total will be the main focus, but also more granular types of deposits were studied and may be mentioned when relevant). These will be used also in natural logarithms, absolute values, or ratios over banks' total assets. Results are qualitatively similar regardless of the measure used. The log measure allows to interpret coefficients as an elasticity, while variables measured in absolute values capture better the mechanical link from excess liquidity to deposits and measured relative to total assets capture the balance sheet dynamics and shifts. Data has monthly frequency and changes (Δ) are defined over a 12-month period. Standard errors are adjusted for autocorrelation in the residuals up to 12 months.

Tables 1 to 3 show the results of the estimation for the period from September 2008 to August 2023, i.e., including the GFC and the sovereign debt crisis and the start of the normalization period of monetary policy. Odd-numbered columns show the correlation without controls and even-numbered columns show the correlation controlling for the slope of the yield curve, as discussed further below. The results confirm the positive correlation between deposits and excess liquidity. In table 1, variables are defined in natural logarithms, so we can interpret coefficients as an elasticity. A 10% increase in excess liquidity is associated with an increase of 0.2% in total deposits (column 1) and 0.1% in demand deposits (column 3), while there is no correlation with time deposits

	$\Delta TotDepo/TA$		$\Delta DemandDepo/TA$		$\Delta TimeDepo/TA$		$\Delta DemandDepoHH/TA$		$\Delta DemandDepoNFC/TA$		$\Delta ExternalDepo/TA$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$\Delta EL/TA$	0.586***	0.592***	0.088	0.085	-0.126***	-0.085*	0.029	0.036	0.069*	0.059	0.078	0.045
	(0.157)	(0.159)	(0.115)	(0.113)	(0.043)	(0.044)	(0.079)	(0.076)	(0.041)	(0.040)	(0.065)	(0.063)
$\frac{EL_{t-12}}{TA_{t-12}}$	-0.011	-0.003	-0.069*	-0.072	-0.045**	0.006	-0.048	-0.039	-0.007	-0.020	0.076**	0.035
	(0.074)	(0.069)	(0.042)	(0.046)	(0.021)	(0.021)	(0.030)	(0.042)	(0.014)	(0.012)	(0.032)	(0.040)
Slope		0.048		-0.021		0.336***		0.058		-0.080		-0.268
		(0.260)		(0.186)		(0.105)		(0.162)		(0.056)		(0.221)
Constant	-0.073	-0.180	0.874***	0.921**	0.083	-0.662***	0.564***	0.437	0.226**	0.404***	-0.538**	0.057
	(0.406)	(0.431)	(0.279)	(0.362)	(0.173)	(0.225)	(0.206)	(0.351)	(0.099)	(0.124)	(0.240)	(0.506)
Observations	180	180	180	180	180	180	180	180	180	180	180	180

Note: Results from estimation of equation (1), for each dependent variable shown in columns. Variables are defined in a ratio of MFI total assets. Δ variables are defined as 12-month changes. Estimation period: September 2008 to August 2023. Standard errors in parentheses adjusted for autocorrelation in the residuals up to 12 months. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Relationship between aggregate deposits and excess liquidity, measured over banks' total assets.

(column 5).[6] The analysis of disaggregated demand deposits by the two main types of depositors, households and non-financial firms, shows that the dynamics come totally from household deposits (columns 7 and 9). As these deposits tend to be a more stable source of funding and insured, possible consequences on banking sector financial stability from banks intentionally increasing these deposits with excess liquidity are milder. Deposits from agents outside the euro area also show a positive correlation with excess liquidity, which may be related to the purchase of assets ultimately owned by investors outside the euro area (Corradin et al., 2020).

The regression can also be estimated in levels, i.e., defining the variables in euro. The results are presented in table 2 and a close to 1-to-1 relationship between excess liquidity and total deposits is found (column 1), as would be expected. Indeed, when the central bank issues reserves, by the balance sheet identity, they end up in deposits. For every euro of extra excess liquidity, around 30 cents end up in demand deposits from the domestic non-financial private sector (column 3) (16 cents for household demand deposits (column 7) and 12 cents for NFC demand deposits (column 9)) and again no significant relationship is found with time deposits. This would suggest that indeed banks do not over-expand their demand deposits following a liquidity expansion. The remaining 70 cents increase is distributed between depositors outside the euro area (columns 11) and other banks' deposits, reflecting the redistribution of liquidity in the financial system.

Table 3 shows the estimation results defining the variables relative to total assets of the banking sector, to understand better the dynamics of the balance sheet as a whole. Despite the 1-to-1 change in total deposits with excess liquidity, this did not imply a similar increase in total deposits relative to banks' balance sheet size. This can be due to the lower share of excess liquidity on banks' balance sheet compared to deposits and to the fact that banks' balance sheet increased less than excess liquidity. The increase in the share of EL is associated with an increase slightly above half in the share of total deposits (column 1). Despite the positive correlation between EL and demand deposits, I do not find a significant correlation when measuring in relative terms (column 3), suggesting that the increase in demand deposits was in the same proportion as the increase in total assets. However, the importance of time deposits diminishes with EL, although it is not statistically significant in absolute terms (column 5). Overall, we observe an increase in demand deposits with excess liquidity, but less than proportionately, and a reduction in the importance of time deposits.

The baseline regression is extended to include the slope of the yield curve (even-numbered columns in tables 1 to 3). When longer-term rates are higher than short-term rates, meaning that the yield curve has a positive slope, depositors may prefer time deposits (or other long-term assets), which yield a higher return. We would thus expect a negative relationship between the slope of the yield curve and demand deposits, allowing to control by some of the drivers of the demand for deposits. As expected, a higher slope is associated with lower demand deposits (column 4) and with higher time deposits (column 6). Controlling for the slope of the yield curve weakens the relationship between deposits and excess liquidity for the overall period. The elasticity of demand deposits to excess liquidity is no longer significant for the full period. Looking at the subsample period beginning in 2014, the elasticities remain broadly unchanged, close to 0.2% for a 10% increase in excess liquidity for demand deposits. The results also remain significant for the regressions in absolute and in relative terms for the shorter period. This suggests that some factors related to the relative demand for short-term deposits and captured by the slope of the yield curve, are less relevant for the period since 2014 and banks' demand for deposits is more directly linked to their holdings of excess liquidity.[7]

The estimated elasticities are below those found for the US (Acharya et al., 2024) and, more

[6] Excluding the sovereign debt crisis period increases the elasticity for demand deposits to 0.2%.

[7] I also controlled for households financial wealth and results are qualitatively similar, but with a loss of data availability, given the lower frequency of this data. For this reason, these results are not shown.

importantly, there is no evidence of a shift from time to demand deposits. Results also seem to be largely driven by household deposits, which tend to be insured and more stable, thus less prone to adverse liquidity shocks. This suggests weaker evidence of liquidity dependencies in the euro area than in the US, although there are several differences between the two areas that make the comparison harder. The banking system is quite different between the two areas and deposits are more concentrated in the US. Universal banks are more common in the euro area and savings are largely intermediated by banks. Central bank liquidity injection was also different between the US and the euro area, with a significant share of it coming from refinancing operations in the euro area, which may also lead to different incentives relative to outright purchases of assets (Altavilla et al., 2023, 2025). As banks may prefer to match their assets and liabilities maturities, funding via temporary refinancing operations could motivate a preference for liquid deposits (Fudulache and Goetz, 2023). As the liquidity provided via these operations matures (which is known in advance), banks may adjust how much demand deposits they are willing to hold again to match maturities in their balance sheet. In case of a liquidity shock, banks can also use the operations to overcome it. Refinancing operations work as an 'insurance' mechanism for banks (assuming no stigma), reducing the liquidity hoarding after a shock. Finally, liquidity regulation is also different in the two areas. Acharya et al. (2024) find that liquidity dependencies are particularly acute for smaller banks that are not subject to the liquidity coverage ratio (LCR). In the euro area, all banks are subject to the LCR. These factors could be a possible justification for the weaker results for the euro area, and that would lead to a more symmetric behavior over the liquidity cycle.

To test for the hypothesis related to the source of the liquidity provision, I start by splitting excess liquidity according to the source of liquidity provision, i.e. temporary refinancing operations or outright asset purchases. Liquidity provided by temporary refinancing operations corresponds to borrowed reserves while that provided by outright purchases corresponds to non-borrowed reserves. The relationship between each type of excess reserves and deposits holds for borrowed reserves but not for non-borrowed reserves, ie, the increase in deposits seems to be related to the endogenous provision of liquidity via temporary refinancing operations. This could be related to a preference to match the maturity of assets and liabilities given the short maturity of refinancing operations. Fudulache and Goetz (2023) show a negative correlation between TLTRO funding and long-term deposits, supporting the hypothesis that banks tend to match assets and liabilities maturities. However, there is no evidence of full symmetry of the evolution of demand deposits over the policy cycle. Another possible justification could be related to the use of standing refinancing operations to cover liquidity risks by the banking sector. If banks assume that the central bank will have available at need a liquidity providing scheme, banks can get more exposed to liquidity risk via increased demand for liquid deposits, which will be easily covered with recourse to the central bank, as the lender-of-last-resort.[8] Given the fixed rate full allotment procedure in place since 2008 in the euro area, it is however not clear the direction of causality between deposits and borrowed reserves, even at the aggregate level.

3.2 The individual bank response to excess liquidity

The aggregate analysis provides a good starting point for understanding the relationship between euro area banks' deposits and central bank liquidity provision. However, as discussed, the positive correlation between excess liquidity and overall deposits can be just the result of a mechanical effect. Thus, one cannot make definite conclusions from the aggregate analysis about how much of the rise in deposits is driven by banks. In order to understand better if banks have indeed changed their behavior intentionally in the face of the extensive excess liquidity available, I explore

[8] Alves et al. (2021) show a clear example of this situation where banks made use of the full allotment procedure to cover for an unexpected and large liquidity shock.

the heterogeneity across banks in the euro area. The first challenge to overcome when going to the cross-section analysis is the endogeneity of deposits and excess liquidity. A bank that receives more deposits may decide to keep it deposited with the central bank. A bank may decide to keep more reserves to cope with deposit withdrawals.

In order to take into account the endogeneity problem, I follow an instrumental variables approach with a Bartik-type of instrument (Acharya et al., 2024; Goldsmith-Pinkham et al., 2020). The instrument builds on the assumption that excess reserves would grow in order to keep the bank's share of excess liquidity over total excess liquidity unchanged, with each bank keeping its position in the liquidity network unchanged. In this way, the demand for reserves by the bank would be exogenous to its deposits evolution and would just follow the exogenous evolution of aggregate excess liquidity determined by the central bank. The instrument is defined by the share of the bank's i excess reserves over total excess liquidity over the past 12 months ($\sum_{k=1}^{12} \frac{EL_{it-12-k}}{EL_{t-12-k}}$) times the aggregate evolution of excess liquidity ($\ln\left(\frac{EL_t}{EL_{t-12}}\right)$), ie:

$$Instrument_{it} = \ln\left(\frac{EL_t}{EL_{t-12}}\right) \frac{1}{12} \sum_{k=1}^{12} \frac{EL_{it-12-k}}{EL_{t-12-k}} \tag{2}$$

The regression analysis is similar to the aggregate data analysis, but now in a 2SLS framework after instrumenting bank-level excess liquidity. The first and second stage regressions are as follows:

First stage:

$$\Delta \ln EL_{it} = \beta_1 Instrument_{it} + \beta_2 \ln EL_{it-12} + \beta_3 X_{it-12} + \theta_{ct} + \epsilon_{it} \tag{3}$$

Second stage:

$$\Delta \ln Deposits_{it} = \alpha_1 \Delta \ln ELinstr_{it} + \alpha_3 X_{it-12} + \delta_{ct} + \varepsilon_{it} \tag{4}$$

where X_{it-12} are lagged bank-level time-varying controls (bank size measured by the log of the bank's total assets and balance sheet capital ratio). Both first and second stage regressions include country-time fixed effects (θ_{ct} and δ_{ct}) to proxy for country factors that affect the evolution of excess reserves and deposits, such as demand for deposits. Assuming that demand for deposits does not vary within the same country is a good proxy for the IBSI sample of banks that excludes very small and new entrants to the banking system, the ones that could be subject to a more specific demand (local or some market niche). The country-time fixed effects also capture similarities between banks from the same jurisdiction.

Table 4 shows the results for the IV regression for the full period since September 2008. The model is adequately identified with the Kleibergen-Paap test pointing to instrument identification with 90% confidence. For reference, column (1) shows the OLS regression, confirming the positive and significant relationship between demand deposits and excess liquidity at the bank level, with a similar magnitude as in the aggregate regression. When excess liquidity is instrumented, and controlling for aggregate trends at the country level, the coefficient on instrumented excess reserves turns insignificant, meaning no impact from exogenous changes in banks' excess reserves on banks' supply of demand deposits (column (2)). By including bank fixed effects to capture potential additional bank unobservable characteristics relevant within jurisdictions, the effect of exogenous changes in excess liquidity on demand deposits remains insignificant. However, this may be a too demanding specification, losing most of the variability in the data.

Table 5 shows the results for the same specification but regarding time deposits. Column (1) shows the OLS estimation results and there appears to be no relationship between bank-level time deposits and their excess reserves held with the central bank, again in line with the results for

	(1)	(2)	(3)	(4)
$\Delta Ln(ELinstr_{it})$	0.053***	-0.097	-0.033	-0.057
	(0.008)	(0.064)	(0.025)	(0.045)
$Ln(TA_{it-12})$	-0.013***	-0.002	-0.279***	-0.303***
	(0.005)	(0.005)	(0.042)	(0.045)
$Equity_{it-12}$	-0.057**	0.146*	0.363***	0.477***
	(0.027)	(0.086)	(0.131)	(0.141)
Constant	0.144***			
	(0.042)			
First stage results				
		$\Delta Ln(EL_{it})$	$\Delta Ln(EL_{it})$	$\Delta Ln(EL_{it})$
$instrument_{it}$		17.293***	44.231***	18.969***
		(4.735)	(12.375)	(4.348)
$Ln(TA_{it-12})$		0.015	-0.366***	-0.188***
		(0.015)	(0.089)	(0.067)
$Equity_{it-12}$		0.374**	0.119	0.220**
		(0.173)	(0.171)	(0.092)
Specification	OLS	IV	IV	IV
Fixed effects	Country-time	Country-time	Bank	Country-time&bank
# banks	2129	1985	1965	1965
S.e.	Cluster bank	Driscoll-Kraay(12)	Driscoll-Kraay(12)	Driscoll-Kraay(12)
N	113573	89701	89681	89681

Note: Results from estimation of equations (3) and (4) for demand deposits defined as M3 deposits as the dependent variable. Column (1) corresponds to the OLS estimator in the second stage, so there is no first stage. Variables are defined in natural logarithms. Δ variables are defined as 12-month changes. Estimation period: September 2008 to September 2023. Robust standard errors in parentheses, clustered at bank level in column (1), adjusted for autocorrelation in the residuals up to 12 months for columns (2) to (4). * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Results of the IV panel regressions for demand deposits.

the aggregate time-series analysis. When taking into account the endogeneity of excess reserves by the IV approach (columns (2)-(4)), there still continues to be no effect from excess reserves on banks' supply of time deposits. Overall, this seems to suggest that there is no evidence that, over the liquidity policy cycle, euro area banks increase their exposure to demand deposits with the expansion of liquidity by the central bank, and no evidence also of a contrary effect on time deposits.

The following question is whether banks' demand for deposits is asymmetric between periods of expanding liquidity or stable/decreasing liquidity. Possible asymmetries over the policy cycle could justify the overall null results and could lead to the relevant policy implications. If banks would expand demand deposits with excess reserves and would continue expanding them when excess reserves fall, the asymmetry over the cycle would not be observed for the full period regression but banks' vulnerability to liquidity shocks would increase. To this end, the sample is split across the three periods of expanding liquidity and the three periods of stable or decreasing liquidity as explained before. I focus now on the baseline specification with country-time fixed effects. Results for the coefficient on banks' exogenous excess liquidity for the regressions with demand and time deposits as dependent variables are shown in Table 6, where the first line shows the results for demand deposits and the second line for time deposits, ie, each line corresponds to the main coefficient of interest, the instrumented changes in excess reserves, of each regression. Columns (1) to (3) show the periods of expanding liquidity, and column (4) shows the results for the regression with the 3 periods bundled together. Similarly, columns (5) to (7) present the results for the periods of stable/declining excess liquidity, and in column (8), these three periods are also bundled together.

The results show that banks increased the supply of demand deposits in the period of expanding liquidity from January 2015 to December 2017. A 10% exogenous increase in banks' excess reserves

	(1)	(2)	(3)	(4)
$\Delta Ln(ELinstr_{it})$	0.008	0.060	-0.004	0.048
	(0.006)	(0.053)	(0.023)	(0.029)
$Ln(TA_{it-12})$	-0.011***	-0.007	-0.125**	-0.108***
	(0.004)	(0.006)	(0.050)	(0.036)
$Equity_{it-12}$	0.013	0.065	-0.052	0.029
	(0.012)	(0.044)	(0.163)	(0.138)
Constant	0.092***			
	(0.035)			
Specification	OLS	IV	IV	IV
Fixed effects	Country-time	Country-time	Bank	Country-time&bank
# banks	2129	1985	1965	1965
S.e.	Cluster bank	Driscoll-Kraay(12)	Driscoll-Kraay(12)	Driscoll-Kraay(12)
N	113573	89701	89681	89681

Note: Results for the (instrumented) variable $\Delta Ln(ELinstr_{it})$ from estimation of equation (4) for time deposits, defined as total deposits minus M3 deposits. First stage results are the same as in table 4. Column (1) OLS estimator; columns (2) to (4) second stage results of IV 2SLS estimator. Variables are defined in natural logarithms. Δ variables are defined as 12-month changes. Estimation period: September 2008 to September 2023. Robust standard errors in parentheses, clustered at bank level in column (1), adjusted for autocorrelation in the residuals up to 12 months for columns (2) to (4). * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Results of the IV panel regressions for time deposits.

	Expanding EL				Stable/decreasing EL			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable	Sep08-Jun12	Jan15-Dec17	May20-Dec21	(1)-(3)	Jul12-Dec14	Jan18-Apr20	Jan22-Sep23	(5)-(7)
$\Delta Ln(DemandDepo)$	-0.071	0.434***	-0.371**	-0.154*	0.077	-1.521	-0.059	0.104
	(0.046)	(0.113)	(0.172)	(0.085)	(0.101)	(15.217)	(0.090)	(0.091)
$\Delta Ln(TimeDepo)$	0.012	-0.161***	-1.220	0.080	-0.059	1.448	-0.531**	0.025
	(0.031)	(0.041)	(0.955)	(0.083)	(0.074)	(14.783)	(0.206)	(0.050)
N	8177	10080	19158	37415	7858	8199	36229	52286
# banks	257	322	1901	1951	265	333	1835	1906

Note: Results for the (instrumented) variable $\Delta Ln(EL_{it})$ from 2nd stage estimation of IV regression for the dependent variable stated in the first column for different sample splits. The sample size is the same for each dependent variable regression. Variables defined in natural logarithms. Δ variables are defined as 12-month changes. Bank controls and country-time fixed effects are included. Standard errors in parentheses adjusted for autocorrelation in the residuals up to 12 months. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 6: Results of the IV regressions for demand and time deposits for different periods.

leads to a 4.3% increase in demand deposits, an effect of significant economic magnitude. The expansion of reserves during this period came mostly from non-borrowed reserves with the APP in place. Moreover, the 2015-2017 period follows the crisis period (GFC and sovereign debt) and the adjustments made by the banking sector of the euro area. Given the post-crisis environment and that liquidity injection through asset purchases mostly comes from an exogenous decision by the central bank, banks' behavior during this period was less affected by factors non-related to monetary policy (financial stability, which could be relevant for the first period, or demand for deposits by households and firms, that is nonetheless controlled for with the country-time fixed effects). During the third period of expanding liquidity in 2020-21, demand deposits evolved in the opposite direction to exogenous changes in excess reserves (column (3)). At the time, the Eurosystem purchased assets under the APP and the PEPP and expanded liquidity via temporary operations. The injection of liquidity was even more substantial than before to respond to a different type of shock (the pandemic). Thus, the background and the sources of primary liquidity could help explain the different results across periods.

When excess liquidity falls, after the expansion that occurred during these two periods, banks did not react in symmetry, i.e., did not reduce the willingness to hold demand deposits, but did not continue to expand either. Banks kept a greater exposure to more liquid deposits, even when central bank intervention was being reduced.

The regression for time deposits as a dependent variable (second line in Table 6) provides further support for the shift towards more liquid liabilities with the central bank liquidity provision. During the period associated with the APP, banks decreased holdings of time deposits following exogenous increases in excess reserves (column (2)). A 10% increase in the bank's excess reserves leads to a 1.6% increase in time deposits. Together with the result for demand deposits, this suggests indeed an intentional shift from longer to shorter-term liabilities. From 2022 onwards, when aggregate excess liquidity began to fall with the policy normalization, time deposits increased with exogenous decreases in excess reserves (column (7)). Following a decrease of 10% in banks' (exogenous) excess reserves, time deposits would increase by 5%. This was at a period when policy interest rates were rapidly increasing, compared to broadly stable policy rates for the two periods before. The inclusion of country-time fixed effects should already take into account the impact of the policy normalization that could justify the increased supply of term deposits by households and firms (Adalid et al., 2024). Thus, the estimated effect should be interpreted on top of the increased supply of time deposits by households and firms.

The above results point out that the possible build-up of liquidity dependencies in the euro area seems to be mostly relevant for the liquidity policy cycle of 2015-2020. The results found both for demand and time deposits for this period point to a shift towards a more liquid liability structure of the balance sheet, intended by banks and as a consequence of QE/QT. Banks would thus be more exposed to liquidity shocks that in turn would make them more dependent on central bank liquidity provision. However, this effect seems to be contained in one of the observed policy cycles (2015-2020). There are two main characteristics from this period: (1) it was a prolonged period of negative policy interest rates and (2) central bank liquidity was driven almost exclusively by asset purchases. Thus, similarly to the US, it could be that it is the liquidity expansion through QE that can change banks' incentives to hold liquid claims. The next step in the analysis aims at understanding better if the source of central bank liquidity is indeed relevant in the build-up of the liquidity dependencies. Banks' excess reserves are split between borrowed and non-borrowed reserves, i.e., between those that come from temporary operations (MRO, LTRO, and TLTRO) and those that come from outright operations that reflect a permanent change in banks' balance sheet (Altavilla et al., 2023). Reserves are instrumented in a similar manner as before, based on the bank's past share of borrowed / non-borrowed reserves. Banks borrowed reserves funded through refinancing operations are made exogenous by assuming that each bank would vary its

	Expanding EL			Stable/decreasing EL		
	(1)	(2)	(3)	(4)	(5)	(6)
	Jan15-Dec17	May20-Dec21	(1)-(3)	Jan18-Apr20	Jan22-Sep23	(5)-(7)
Panel A: Dependent variable: $\Delta Ln(DemandDepo)$						
$\Delta\ Ln(BR\ inst_{it})$	0.997	-0.102	1.084	-0.066	-0.546	0.104
	(0.696)	(0.266)	(0.972)	(0.584)	(1.018)	(0.287)
$\Delta\ Ln(NBR\ inst_{it})$	0.394***	0.007	0.553***	0.393	-0.237	0.024
	(0.107)	(0.115)	(0.201)	(0.344)	(0.359)	(0.119)
N	4187	19158	23345	8199	36229	44428
Panel B: Dependent variable: $\Delta Ln(TimeDepo)$						
$\Delta\ Ln(BR\ inst_{it})$	-0.263**	1.660	-0.466	0.988	-0.684	-0.643
	(0.094)	(2.237)	(0.486)	(0.774)	(0.625)	(0.482)
$\Delta\ Ln(NBR\ inst_{it})$	-0.069	0.839	-0.140	-0.753***	-0.346	-0.339*
	(0.053)	(0.764)	(0.155)	(0.215)	(0.239)	(0.182)
N	4187	19158	23345	8199	36229	44428

Note: Results for the (instrumented) variables Δ Ln(Bank Borrowed Reserves) and Δ Ln(Bank Non-Borrowed Reserves) from 2nd stage estimation of IV regression for the dependent variable stated in the first line of each panel for different sample splits. The sample size is the same for each dependent variable regression. Variables are defined in natural logarithms. Δ variables are defined as 12-month changes. Bank controls and country-time fixed effects are included. Robust standard errors in parentheses, clustered at bank level in column (1), adjusted for autocorrelation in the residuals up to 12 months for columns (2) to (4). * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Results of the IV regressions using borrowed / non-borrowed reserves as the main explanatory variable.

reserves proportionately to the aggregate liquidity injection via refinancing operations. Similarly, non-borrowed reserves would also evolve proportionately to aggregate liquidity injection by asset purchases, assuming that the banks' relevance as a money center is kept based on the past holdings of non-borrowed reserves. The instruments are then set as:

$$BR\ Inst_{it} = \ln\left(\frac{BR_t}{BR_{t-12}}\right)\frac{1}{12}\sum_{k=1}^{12}\frac{BR_{it-12-k}}{BR_{t-12-k}} \tag{5}$$

$$NBR\ Inst_{it} = \ln\left(\frac{NBR_t}{NBR_{t-12}}\right)\frac{1}{12}\sum_{k=1}^{12}\frac{NBR_{it-12-k}}{NBR_{t-12-k}} \tag{6}$$

Results for demand and time deposits are shown in Table 7, with the same split across time as before but excluding the first periods of expanding and decreasing excess liquidity because of a lack of observations with non-borrowed reserves. During the APP-led liquidity expansion (column (1)), as suspected, the increased supply of demand deposits came from the non-borrowed reserves (panel A). Moreover, the expansion of borrowed reserves also contributed to the decrease in time deposits (column (1), panel B). A 10% exogenous increase in a bank's non-borrowed reserves induced a 3.9% increase in demand deposits, in line with elasticity found for total excess reserves. A 10% increase in a bank's borrowed reserves induced a 2.6% fall in time deposits. The shift from time to demand deposits may be rationalized with the interaction between the two types of liquidity provision that reinforce each other. Banks may be only willing to expand demand deposits following asset purchases, as this provides them a "permanent" source of primary liquidity. Moreover, banks are only willing to do so at the expense of time deposits if the central bank also increases liquidity through refinancing operations, which can act as a liquidity insurance mechanism.

For the periods of decreasing excess liquidity, I only get a significant negative effect from non-borrowed reserves on time deposits after the APP-led liquidity expansion period, and with a large magnitude of a 7.5% increase after a 10% decrease in non-borrowed reserves (column (4)). No significant effect is found for demand deposits. This suggests that the build-up of potential liquidity vulnerabilities varies through the cycle. Although demand deposits do not revert when the ECB shrinks the balance sheet, banks increase time deposits with changes in non-borrowed reserves. It seems as if there is some adjustment occurring in the balance sheet of the banks but not totally symmetric over the policy cycle, keeping still potential vulnerabilities open.

Altavilla et al. (2023) show that the liquidity expansion, especially that coming from asset purchases and TLTROs (regarding TLTROs effect on credit, see Benetton and Fantino (2021), Afonso and Sousa-Leite (2020), Andreeva and Garcia-Posada (2021), among others) contributes significantly to the credit expansion, but do not take a stand on the direction of causality with deposits. The results described above provide support to a channel in line with the "money multiplier" for the APP-led liquidity expansion, as would be consistent with an increased supply of demand deposits coming from the APP liquidity and the increase in credit. Banks may prefer outright liquidity injections (or temporary ones with lending incentives) to expand credit, while reversible liquidity provision is taken by banks as a "liquidity insurance", especially with a full allotment procedure in place, that allows them to match closer the maturities of their assets and liabilities, without the need for actively seeking the expansion of the banks' liquid liabilities.

Overall, results point to more benign consequences from the build-up of potential liquidity dependencies in the euro area than in the US. In both areas, the dependency on the supply of liquidity in the euro area seems to be more related to liquidity provision coming from asset purchases, as shown above. However, in the euro area, this is possibly related to the low and stable interest rate environment with relatively low macro risk. Another of the possible factors for the milder effects in the euro area that is not tested in the paper relates to the different liquidity regulations in the two areas. Indeed, in the euro area liquidity regulation applies to all banks, while in the US small and medium-sized banks can be exempt from it. As the SBV-crisis episode in March 2023 shows, this can lead these banks to vulnerabilities to liquidity shocks that can spread to other banks and have large negative consequences. Thus, the regulatory cost of holding liquid claims may be contributing to the lower liquidity dependency observed in the euro area relative to the US.

In order to best understand the mechanism driving the dynamics between excess liquidity and liquid deposits, further analysis is conducted by splitting the sample depending on the type of bank. Banks are split by size, by equity ratio, and by the funding structure of the bank, i.e. by the importance of deposit funding, proxied by the deposit ratio over total assets (results are shown in annex, Table A.2 for demand deposits and Table A.3 for time deposits).[9] Results show that the expansion in demandable deposits during the APP period comes from banks less reliant on deposit funding, with lower equity ratios, smaller and that did not participate in TLTRO. When aggregate excess liquidity decreases, there is overall no meaningful relationship. The reduction in time deposits with excess reserves during the APP period is more relevant for small banks and banks participating in TLTRO. During the normalization of monetary policy starting in 2022, the increase in time deposits with excess reserves came mostly from banks with a higher share of deposits in their balance sheet.

The results for the sample splits highlight possible dynamics for some banks, namely those that can be more constrained and benefit more from an increase in funding through deposits. First, results could be consistent with the hypothesis that banks less reliant on deposits make more active management of their deposit funding when central bank liquidity expands. Banks with fewer deposits could be using the ample liquidity environment to increase their reliance on deposit funding, especially short-term. Additionally, results seem to favor some increase in liquidity dependencies from more constrained banks (lower equity and smaller). Such banks could have a greater incentive to catch cheaper and more liquid deposits in the ample liquidity environment, with lower funding costs than alternative sources. The banks that could be potentially more risky are the ones that continue to potentially increase their liquidity risk. The fact that this seems to be only relevant for the APP period suggests a mechanism similar to the risk-taking channel. During a period of low and stable interest rates and ample liquidity, there is a greater build-up of vulnerabilities among the most vulnerable banks ex-ante.

The sample is also split between TLTRO-participating and non-participating banks, ie banks that have made recourse at least once to one of the three series of TLTRO.[10] Using this split is

[9] The samples are split each month by the median value of each relevant variable.
[10] Participating banks represent around 46% of the sample.

also a way to proxy for banks more reliant on ECB refinancing operations. The results on the TLTRO-participating banks' sample split show that non-participating banks increased demand deposits following exogenous increases in excess reserves during the APP period. When liquidity started to fall, these banks did not revert the holdings of demand deposits. In turn, TLTRO-participating banks decreased demand deposits following an exogenous fall in the excess reserves during the liquidity expansion period of the pandemic and the liquidity decreasing period afterward. The results on non-participating banks provide support to the hypothesis that the build-up of liquidity dependencies would come up mostly from liquidity injected through QE. The results for participating banks suggest that banks consider indeed refinancing operations as a temporary source of liquidity, with a pre-determined redemption date, and do not have the incentive to change their behavior. In this case, either there is no effect from reserves or the effect is symmetric over the policy cycle, with banks minimizing the assets and liabilities maturities mismatch.

3.3 Effects on deposits' interest rates

So far, the effects have been tested only in the amount of deposits. If banks would really change their supply of deposits in tandem with their excess reserves, one could also expect an effect on the pricing of deposits. For instance, banks could increase the interest rate in demand deposits relative to time deposits in order to attract relatively more demand deposits or even to incentivize the shift from time to demand deposits.

To test this hypothesis, I look at the spread at the bank level between interest rates on new deposits with agreed maturity over two years (the proxy for time deposits) and the interest rate on overnight deposits, i.e., the most liquid type of deposits that banks can offer, and regress against the level of excess reserves and deposits. Endogeneity is taken care of again with an IV approach, using a Bartik-type of instrument. For excess reserves, the same instrument as before is used. Deposits are instrumented by assuming that the bank would keep its past 12-month share of total deposits in the country and would thus have the same change in deposits as in the country the bank is located at. In this way, changes in deposits are as if coming from other exogenous sources not related to the demand or supply of deposits. Summarizing, the deposits instrument is given by the expression below, where c is an index for the country and i for the bank:

$$DepoInstrument_{it} = \ln\left(\frac{TotalDeposits_{ct}}{TotalDeposits_{ct-12}}\right)\frac{1}{12}\sum_{k=1}^{12}\frac{TotalDeposits_{it-12-k}}{TotalDeposits_{ct-12-k}} \tag{7}$$

As before, country-time fixed effects are included to capture macroeconomic conditions and other factors that may affect banks' deposit rates in the same way in the same country at the same time.

Results for the second stage regression are shown in Table 8 for different sample splits over time. The coefficient on the exogenous changes in banks' deposits is usually negative, meaning banks tend to reduce the spread on time deposits as they receive more deposits from clients. The coefficient on the exogenous changes in excess reserves is negative for the periods of expanding aggregate excess liquidity, but only statistically significant for the period of 2020-21. Banks tended to decrease the interest rates on time deposits relative to overnight deposits, which would be consistent with banks trying to attract more demand deposits with increases in excess reserves. For the periods of decreasing excess liquidity after 2018, there is no significant response on the deposit rate spread from changes in excess reserves. During the period between 2012 and 2014, the coefficient on banks' excess reserves is positive and significant for the period of decreasing excess liquidity just after the GFC and the sovereign debt crisis (July 2012-December 2014). This suggests that banks pushed down the spread between time and demand deposit rates as their excess reserves fall, which could disincentive the build-up of time deposits and incentivize demand deposits. However, this

	Expanding EL				Stable/decreasing EL			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Sep08-Jun12	Jan15-Dec17	May20-Dec21	(1)-(3)	Jul12-Dec14	Jan18-Apr20	Jan22-Aug23	(5)-(7)
$Ln(ELinst_{it})$	-0.008	-0.042	-0.051**	-0.025	0.394**	-0.047	-2.548	1.102
	(0.135)	(0.026)	(0.022)	(0.032)	(0.162)	(0.061)	(21.609)	(3.289)
$Ln(DepoInst_{it})$	-0.693	-0.288***	-0.305***	-0.393***	2.081	-0.472***	0.728	-0.271
	(0.640)	(0.069)	(0.042)	(0.071)	(1.807)	(0.080)	(11.112)	(2.130)
N	4132	4969	2211	11312	4086	3505	2169	9760

Note: Results from 2nd stage estimation of IV regression for the interest rate spread between deposits with agreed maturity above 2 years and overnight deposits as the dependent variable for different sample splits. Regressors are defined in natural logarithms. Bank controls and country-time fixed effects are included. Robust standard errors in parentheses, clustered at bank level in column (1), adjusted for autocorrelation in the residuals up to 12 months for columns (2) to (4). * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Results of the IV data regressions for the interest rate spread between time and overnight deposits.

was a period when banks were still adjusting their balance sheets after the banking and sovereign crisis.

4 Concluding remarks

In this work, I have discussed the extent to which euro area banks could have changed their behavior following the significant liquidity injection over the past decade, in particular in a way that could make the banking system more vulnerable to liquidity shocks and dependent on central bank liquidity. Overall, the results provide support to banks increasing their liquidity exposure when the Eurosystem expanded the balance sheet, but only during the APP period, without a reversal when the balance sheet begins to shrink. This increased exposure seems to be driven mostly by banks that could benefit more from deposits as a cheaper source of funding and mostly by liquidity injected through the large-scale asset purchase programs in a context of very low and stable interest rates, very low inflation, and limited macroeconomic risk.

The study has relevant policy implications. For the operational business of central banks, these need to take into account the shifts in the demand for reserves relative to the past, largely influenced by the quantitative policy measures taken by the Eurosystem. If banks prefer to keep a greater exposure to liquid liabilities, they may have a greater demand for reserves. As the Eurosystem progresses with the contraction of its balance sheet, it is imperative to consider this demand for reserves that diverges from historical norms. Moreover, the potential increased vulnerabilities of banks to liquidity shocks implies that the Eurosystem may need to intervene more often, thus the need for an ample and flexible operational framework. Finally, the limited data points with decreasing excess liquidity available for analysis would advise to continue monitoring this issue and the potential recalibration of the operational framework.

In the short to medium term, diminishing liquidity warrants close scrutiny of liquidity shocks, which may now pose greater risks than previously anticipated. Banks might adopt a more conservative stance, hoarding liquidity to safeguard against potential volatility. This behavior, while a rational response to uncertainty, could undermine financial stability, potentially necessitating preemptive central bank interventions to mitigate systemic risks. This underscores the need for robust frameworks to monitor and manage liquidity fluctuations effectively, ensuring that the banking sector remains resilient in the face of adverse conditions.

In the long-term, particularly as central banks might again need to expand liquidity the long-term side effects of different options to do so need to be taken into account. The study suggests that the extensive liquidity injections of the past decade have reshaped banks' preferences for liquidity and risk that are not symmetric over the cycle and depend on the instruments used and on the macroeconomic context.

Further research is still needed to better understand the changed incentives of banks. There are still nuanced differences between the Euro area and the US that need further discussion in particular related to liquidity regulation that differ across the two regions and are likely to be relevant for the mechanism at play.

A Additional tables and figures

	Average	Stdev	P(10)	Median	P(90)	N. obs
Demand deposits	8 874	26 842	1	1 361	19 490	143 527
Time deposits	2 173	8 224	0	29	4 975	143 527
Excess reserves	1 537	7 153	0	52	2 286	143 527
Borrowed reserves	956	4 598	0	0	1 317	143 527
Non-borrowed reserves	581	5 626	-312	9	1 464	143 527
Total assets	29 964	95 226	195	3 659	61 801	143 527
Equity ratio	10.6%	31.3%	2.3%	9.4%	17.3%	139 889

A.1: Summary statistics of main variables at the bank level. All variables except equity ratio are in million euro.

	Expanding EL				Stable/decreasing EL			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sample	Sep08-Jun12	Jan15-Dec17	May20-Dec21	(1)-(3)	Jul12-Dec14	Jan18-Apr20	Jan22-Sep23	(5)-(7)
Low deposit ratio	-0.141**	0.322***	-0.973	-0.290	0.116	-0.977	-0.243*	0.173
	(0.067)	(0.074)	(0.783)	(0.200)	(0.221)	(18.240)	(0.126)	(0.203)
N	4020	4944	8161	17125	3929	5309	17667	26905
High deposit ratio	0.037	-0.025	-0.145	0.025	0.130***	-0.074	0.051	0.133**
	(0.031)	(0.084)	(0.101)	(0.025)	(0.046)	(0.293)	(0.185)	(0.055)
N	4108	5066	10899	20073	3857	2768	18549	25174
Small banks	0.055	0.774**	0.068	-0.008	-0.106***	0.032	-0.548	-0.128***
	(0.039)	(0.295)	(0.041)	(0.089)	(0.031)	(0.032)	(1.389)	(0.041)
N	3584	4428	8332	16344	3681	1778	17715	23174
Large banks	-0.154***	0.326**	5.273	-0.195*	0.334	-1.963	-0.056	0.350
	(0.030)	(0.120)	(10.630)	(0.101)	(0.504)	(13.879)	(0.164)	(0.514)
N	4529	5607	10733	20869	4127	6293	18503	28923
Low equity ratio	-0.111***	0.547***	-0.575**	-0.224*	0.076	-1.216	-0.054	0.105
	(0.029)	(0.193)	(0.243)	(0.130)	(0.171)	(6.484)	(0.129)	(0.126)
N	4071	4886	9035	17992	3864	4932	18077	26873
High equity ratio	0.038	0.412*	-0.688*	0.000	0.146*	0.239**	-0.578	0.159
	(0.044)	(0.209)	(0.383)	(0.045)	(0.077)	(0.098)	(0.672)	(0.097)
N	4006	5077	10043	19126	3919	3156	18142	25217
TLTRO banks	0.013	-0.255	-0.773**	0.165	-0.213	-0.191	-0.206**	-0.077
	(0.028)	(0.212)	(0.345)	(0.230)	(0.146)	(0.270)	(0.095)	(0.110)
N	5025	5766	10062	20853	4595	4504	16010	25109
Non-TLTRO banks	-0.085	0.666***	-0.123	-0.198*	0.165	0.981	0.009	0.179
	(0.051)	(0.146)	(0.200)	(0.114)	(0.169)	(4.536)	(0.128)	(0.176)
N	3098	4236	8982	16316	3203	3560	20219	26982

Note: Results for the instrumented variable Δ Ln(BankEL) from the estimation of equation (4) for demand deposits for different periods according to the type of bank. Sample splits by median of the relevant bank characteristic at each month. Δ variables are defined as 12-month changes. Regression includes bank controls and country-time fixed effects. Robust standard errors in parentheses, adjusted for autocorrelation in the residuals up to 12 months. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

A.2: Results of the panel data regressions for different sample splits with demand deposits as the dependent variable.

	Expanding EL				Stable/decreasing EL			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sample	Sep08-Jun12	Jan15-Dec17	May20-Dec21	(1)-(3)	Jul12-Dec14	Jan18-Apr20	Jan22-Sep23	(5)-(7)
Low deposit ratio	0.031	-0.067	-2.073	0.125	-0.170	-3.478	-0.271	-0.103**
	(0.063)	(0.048)	(2.174)	(0.164)	(0.102)	(67.058)	(0.236)	(0.048)
N	4020	4944	8161	17125	3929	5309	17667	26905
High deposit ratio	-0.017	0.629	-0.212*	-0.064	0.145**	-0.148	-1.262***	0.219***
	(0.040)	(0.701)	(0.105)	(0.083)	(0.057)	(0.657)	(0.390)	(0.072)
N	4108	5066	10899	20073	3857	2768	18549	25174
Small banks	0.063*	-0.749***	-0.007	0.173	-0.131**	-0.104**	0.058	-0.099
	(0.034)	(0.131)	(0.035)	(0.131)	(0.059)	(0.051)	(0.127)	(0.068)
N	3584	4428	8332	16344	3681	1778	17715	23174
Large banks	0.065	-0.259***	3.233	0.158	-0.180*	1.252	-0.443*	0.030
	(0.081)	(0.092)	(5.667)	(0.170)	(0.104)	(9.373)	(0.253)	(0.117)
N	4529	5607	10733	20869	4127	6293	18503	28923
Low equity ratio	0.013	-0.050	-0.956	0.043	-0.116	0.902	-0.359*	0.012
	(0.037)	(0.145)	(0.561)	(0.074)	(0.119)	(4.817)	(0.204)	(0.071)
N	4071	4886	9035	17992	3864	4932	18077	26873
High equity ratio	-0.007	-0.628	-0.585***	0.084	-0.004	0.077	1.940	0.050
	(0.053)	(0.606)	(0.134)	(0.106)	(0.051)	(0.217)	(1.229)	(0.071)
N	4006	5077	10043	19126	3919	3156	18142	25217
TLTRO banks	0.064	-0.486*	-1.216	0.368	-0.371*	-0.024	-0.777*	-0.197
	(0.073)	(0.255)	(0.840)	(0.447)	(0.201)	(0.044)	(0.374)	(0.146)
N	5025	5766	10062	20853	4595	4504	16010	25109
Non-TLTRO banks	-0.012	0.007	-1.428*	0.018	-0.020	-2.750	-0.993	0.067
	(0.042)	(0.187)	(0.713)	(0.078)	(0.058)	(10.798)	(0.766)	(0.074)
N	3098	4236	8982	16316	3203	3560	20219	26982

Note: Results for the instrumented variable Δ Ln(BankEL) from the estimation of equation (4) for time deposits for different periods according to the type of bank. Sample splits by median of the relevant bank characteristic at each month. Δ variables are defined as 12-month changes. Regression includes bank controls and country-time fixed effects. Robust standard errors in parentheses, adjusted for autocorrelation in the residuals up to 12 months. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

A.3: Results of the panel data regressions for different sample splits with time deposits as the dependent variable.

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Acknowledgements

I am thankful for research assistance from L. Sousa Faria and K. Castro Vasquez and for comments and suggestions from D. Andreeva, D. Bonfim, L. Burlon, F. Holm-Hadulla, D. Kedan, S. Pool and one anonymous referee.
The opinions expressed in this article are those of the authors and do not necessarily coincide with those of the ECB, the Banco de Portugal or the Eurosystem.

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PDF ISBN 978-92-899- 7229-1 ISSN 1725-2806 doi:10.2866/ 1157615 QB-01-25-111-EN-N