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Barbara Meller, Oscar Soons

## Know your (holding) limits: CBDC, financial stability and central bank reliance

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# Contents

# Abstract

How do central bank digital currencies (CBDC) impact the balance sheets of banks and central banks? To tackle this question empirically, we built a constraint optimisation model that allows for individual banks to choose how to respond to outflows of deposits, based on cost considerations and subject to the availability of reserves and collateral, within the individual banks and system wide, and for a given level of liquidity risk tolerance. We simulate the impact of a fictitious digital euro introduction in the third quarter of 2021, using data from over 2,000 euro area banks. That impact depends on i) the number of deposits withdrawn and the speed at which this occurs, ii) the liquidity available within the banking system at the time of the digital euro introduction, iii) the liquidity risk preferences of the markets and supervisors, iv) the bank's business model, and v) the functioning of the interbank market. We find that a €3,000 digital euro holding limit per person, as suggested by Bindseil (2020) and Bindseil and Panetta (2020), would have been successful in containing the impact on bank liquidity risks and funding structures and on the Eurosystem balance sheet, even in extremely pessimistic scenarios.

**JEL codes:** E52, E58, G21.

**Keywords:** digital currency, financial intermediation, financial stability, liquidity risk.

# Executive Summary

Central banks throughout the world are investigating the potential benefits and risks of introducing CBDCs or not. In this paper, we propose a model to simulate how the balance sheets of banks and central banks might be impacted by the loss of banks' deposit funding should a CBDC be introduced. We simulate the impact of a fictitious digital euro introduction in 2021 using detailed bank-level data. When interpreting the results, we pay particular attention to outflows compatible with a €3,000 holding limit, as suggested by Bindseil (2020) and Bindseil and Panetta (2020).

When a retail depositor withdraws funds from a bank in order to hold CBDC, its bank will need to transfer central bank reserves to the central bank. Should a bank hold insufficient banknotes and reserves to meet the demand for CBDC, it has different options to borrow reserves: short term or long term, on the secured or unsecured interbank market or from the central bank. A bank will choose between those options based on the relative costs they involve, but also based on the impact on its liquidity buffers and subject to the availability of collateral and market liquidity. The deposit outflows, reserve holdings and liquidity buffers of the other banks therefore determine the available options of each bank. Our constraint optimisation model captures these different considerations.

In our case study, we simulate the impact of a fictitious digital euro introduction in the third quarter of 2021 using euro area bank balance-sheet data and illustrate a) how banks might have restructured their balance sheets in the immediate aftermath, and b) how much additional reserve demand the Eurosystem would have faced. We analyse the impact under different liquidity risk tolerance scenarios. Under our baseline scenario, banks have an intermediate liquidity risk appetite and wish to keep half of the bank-specific voluntary liquidity buffers they held in excess of the regulatory minimum. In this scenario and with a holding limit of €3,000 per person in place, we find that bank funding structures would not have changed extraordinarily and no additional Eurosystem funding would have been needed.

We also simulate the impact of a digital euro with 2019 data, a time when reserves were lower. Moreover, we adjust our model specification to study the impact of a segmented rather than perfectly functioning interbank market as well as the impact of a bank run where there is not interbank market. The simulations in these cases likewise show that the impact would have been relatively benign, provided a digital euro holding limit of €3,000 per person would be in place.

Market and policy rates, collateral and reserve availability, liquidity buffers and banks' willingness to draw these down, are all important determinants in banks' portfolio choices. These factors interact and change over time. Also, the central bank would pre-emptively take into account an upcoming digital euro when deciding on its operational framework and its supply of reserves. To properly gauge the actual impact of a digital euro across euro area banks and EU Member States, it is therefore necessary to repeat these simulations using data and accounting for the prevailing operational framework at the time of a possible digital euro introduction.

# 1 Introduction

**Central banks throughout the world are investigating the potential benefits and risks of introducing CBDCs or not.** A successful (retail) CBDC would lead to (retail) customers shifting part of their funds away from bank deposits to central banks. An often-cited concern in this regard is a consequent increase in banks' funding risks and a decrease in bank lending (Eurosystem, 2021).[1] In this paper, we examine the former and study how banks might adjust their balance sheets in response to a loss of retail deposit funding (overnight household deposits), and what the potential implications might be for banks' liquidity risks and the demand for excess reserves. We focus on the short-term impact, assuming bank lending remains constant.

**When a retail depositor withdraws funds from a bank to exchange them for digital euros, its bank will need to transfer central bank reserves to the central bank.** As detailed in Adalid et al. (2022), a bank can obtain CBDC by transferring either banknotes or central bank reserves to its central bank. Should a bank have insufficient banknotes and reserves to meet the deposit outflow, it could acquire new reserves on the interbank market or from the central bank. The bank would choose how to adjust its balance sheet based not only on the relative costs of these options, but also on their impact on its liquidity buffers and the availability of excess reserves and collateral.

**We built a model that allows individual banks to adjust their balance-sheet in reaction to a retail deposit outflow based on cost-efficiency and subject to their own but also other banks' liquidity preferences, reserve constraints and collateral availability.** In choosing how to respond to deposit outflows, banks are constrained by their holdings of reserves and collateral and face a trade-off between funding costs and liquidity risks, which is not trivial.[2] Also, banks' options when tapping the interbank depend not only on their own preferences but also on the deposit outflows, reserve holdings and liquidity buffers of the other banks. Allowing banks to endogenously select their preferred balance-sheet adjustments poses therefore a complex optimisation problem.

**Our main contribution is to develop a detailed simulation model of the changes to each and all banks' liability positions, reserve holdings and regulatory liquidity ratios.** In contrast to the existing literature, our model and data make it possible to assess the impact on and off the two key liquidity requirements,

1 In this paper, we are not discussing the benefits of introducing a digital euro. For this, we refer to Panetta (2021), who among other benefits points out the monetary anchor role of a digital euro: "[C]onvertibility into central bank money is therefore necessary for confidence in private money, both as a means of payment and as a store of value".

2 For instance, short-term unsecured borrowing has a higher run-off rate than overnight household deposits. Consequently, it would increase the LCR denominator (expected outflow) and would not count as stable funding for the NSFR. While medium-term secured borrowing does not negatively impact expected outflows, it needs to be backed by collateral, which reduces the LCR numerator (unencumbered HQLAs) and increases the NSFR denominator (required stable funding). Furthermore, for both types of interbank market funding, the reserves of the bank that provides liquidity on the interbank market decrease, which lowers its LCR numerator and also increases its NSFR denominator.

namely the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR), applying the requisite information on asset haircuts and liability run-off rates. These regulatory ratios constrain banks' funding options and are therefore important determinants for their balance sheet composition, influencing banks' choice to revert to the interbank market or the central bank. The model also incorporates each banks' reserve holdings and available unencumbered central bank eligible collateral and continuously updates this information during the simulation. For the interbank market, secured and unsecured funding options with different maturities and haircuts and their impact on liquidity ratios for banks on both sides of the transactions are also included in the model. For central bank funding, various types of central bank funding are considered, including short-term and long-term funding secured by high quality liquid assets (HQLAs), eligible non-HQLAs, or currently non-eligible collateral. The existing empirical literature, so far, disregards either the NSFR or liquidity regulation altogether, ignores the (limitations of the) interbank market as well as collateral and/or reserve availability, and considers a subset of adjustment options in isolation.

**We apply our model to illustrate the impact of a fictitious digital euro introduction in 2021 on the balance sheets of euro area banks and the Eurosystem.** Our baseline simulation uses balance-sheet assets and liabilities data for the third quarter of 2021– the most recent data available at the time of our analysis – for more than 2,000 euro area banks, thereby encompassing more than 95% of the euro area banking sector assets. In terms of liquidity risk tolerance, our baseline scenario (Scenario B) assumes that banks would be willing to draw down half of the voluntary liquidity buffers they hold in excess of the regulatory minimum, which is equal to their median observed annual changes. We also assume that banks would be willing to provide liquidity on the interbank market, provided this does not increase their liquidity risk beyond their preferred levels. Regarding the relative funding costs, we make the reasonable assumption that short-term liquidity would be cheaper than long-term liquidity, secured funding less costly than unsecured funding and market funding less expensive than central bank funding of a similar maturity provided that the overall amount of excess liquidity in the system is sufficient.[3]

**We simulate banks' responses to a withdrawal of overnight retail deposits, focusing on the most extreme outflows compatible with a digital euro holding limit of €3,000 per person.** In our empirical assessment, we simulate banks' responses to overnight retail deposit outflows, given that these deposits are arguably the closest substitute for a digital euro. Bindseil (2020) and Bindseil and Panetta (2020) suggest that the maximum deposit outflow could be restricted by imposing a €3,000 digital euro holding limit per person. In the euro area, that limit would mean a maximum deposit outflow of €1.0 trillion if each and every euro area resident were to

3 Regarding the pricing of the different funding options, we deviated from the rates observed in 2021. At the time of the simulation, using TLTROs would have been the dominant strategy for all banks with access to that option given their attractive pricing and that such operations have no negative impact on liquidity ratios if collateralised against eligible non-high-quality liquid assets (HQLAs). TLTROs would, in fact, have improved bank profitability since they earn interest, while retail deposits were not generally renumerated. However, we excluded the option of TLTROs on the ground that they are unlikely to prevail.

adopt the digital euro and would continuously prefund the digital euro up to the maximum holding limit solely through their bank deposits. Clearly, it is unlikely that all residents would fully utilise their limit of €3,000, which could be more than their monthly income, on a continuous basis and solely by deposit substitution. Accordingly, outflows of €1.0 trillion are assumed to be the "most extreme", while larger outflows are deemed to be "unrealistic".[4]

**Based on 2021 data, we find that even with the most extreme retail deposit outflows, the digital euro would have had little impact on the Eurosystem balance sheet beyond a swap of counterparties from banks to households.** With low deposit outflows, the Eurosystem would not have needed to provide additional reserves to banks, assuming banks were willing to use half of their voluntary liquidity buffers. Banks would have preferred cheaper interbank funding rather than recourse to the Eurosystem. The interbank market redistributes excess reserves from banks with high reserve holdings and high liquidity buffers to banks in need of reserves. The question that arises is at what outflow the Eurosystem would need to supply additional reserves to avoid stress on the interbank market, which happens when all banks reach their liquidity risk tolerance limit, meaning that they would be reluctant to provide further liquidity on the interbank market.[5] Under our baseline liquidity risk tolerance scenario (Scenario B), the banking system could have accommodated an outflow of 20% of retail deposits by merely drawing down existing excess reserves and not requiring additional reserves from the central bank. The 20% of retail deposits equate to €1.4 trillion, which exceeds the most extreme outflow of €1.0 trillion. It is only in the highly unlikely event of higher outflows that banks need to obtain additional reserves from the Eurosystem against eligible collateral. Naturally, if outflows were extremely high, some banks would run out of currently eligible collateral. Under Scenario B, we find that it is only when outflows would have exceeded around 30% of retail deposits, equating to €2.1 trillion (more than double the most extreme outflow), that one-tenth of the central bank funding required could not have been secured against currently eligible collateral.

**Even with the most extreme outflows, the shift in banks' funding structures away from retail and towards wholesale and central bank funding would not have been unusual.** Using data for the third quarter of 2021 and assuming that banks maintain half of their voluntary liquidity buffers, we find that even with the most extreme outflows, only a few banks would have experienced an extreme increase in their reliance on central bank or wholesale funding. It is only when outflows exceeded 28% of retail deposits, equating to a total of €1.9 trillion, that a more significant proportion of the banking sector (over 10% in terms of total assets) would have experienced an extreme increase in its wholesale funding reliance when compared to historical quarterly changes. We use historical data to argue that a slow phase-in of the digital euro, that lasts longer than a quarter, would render the

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4 For comparison, euro banknotes in circulation currently amount to about €1.6 trillion.

5 The Eurosystem provides additional liquidity when excess liquidity reaches the floor required excess liquidity (FREL) level to ensure a smooth transmission of monetary policy. In our model, this point is reached when banks are no longer willing to provide more funding because it would result in their liquidity levels being lower than they would prefer.

increases in central bank funding reliance and wholesale funding dependence even more moderate compared to historical annual changes.

**The impact of a digital euro with a €3,000 holding limit also remains moderate when running simulations using data for the third quarter of 2019, an economic environment with less excess liquidity, or when assuming a segmented interbank market or a potential bank run scenario.** Clearly, if the input or assumptions for our model were to change, the outcome of the simulated impact of a CBDC introduction would also change. To illustrate this, we first apply the model to euro area balance-sheet data for the third quarter of 2019, when reserves were less ample and there was therefore less excess liquidity. This simulation shows a benign impact on banks that is similar to that in our baseline scenario. There are two reasons for this potentially surprising finding. First, banks held lower reserves but had more eligible collateral in 2019 as compared with the third quarter of 2021. They could therefore use this collateral to obtain reserves when needed. Second, banks had fewer retail deposits in 2019 as compared with the third quarter of 2021. We then simulate the model relaxing the assumption of a frictionless interbank market. We find that when banks only borrow and lend on a national interbank market, it almost makes no difference to the conclusions drawn from the more benign baseline scenario. Finally, we show that our model could be used to calibrate digital euro holding limits that would contain a digital euro's impact on banks' liquidity risks during a system-wide stress period. We find that a digital euro's impact on banks' liquidity risks in a bank run scenario would have been contained in the event of a €3,000 holding limit. All our results are summarised in Table 2.A, Table 2.B and Chart 14 at the end of this paper.

**Our model could be used to guide policy-makers decision-making on the design and timing of a future digital euro introduction.** While a successful digital euro requires uptake by euro area residents, it should not be used too much to avoid financial stability risks (Ahnert et al., 2022). A digital euro holding limit might prevent excessive use of a digital euro. Obviously, the simulation results given in this paper cannot be used to predict the response of banks if and when a digital euro is introduced, given that economic situations, market rates and bank balance sheets are subject to change, and this would be particularly true if an introduction were to be anticipated. Similarly, also the central bank would pre-emptively take into account an upcoming digital euro when deciding on its operational framework and its supply of reserves. Therefore, policy makers will need to re-run our model close to the time of a digital euro introduction to gauge the impact on the balance sheets of the Eurosystem and banks within the changed environment. Such simulation could distinguish between the impact on business models and Member States and be useful for the calibration of digital euro holding limits, if policy makers wish to impose those.[6]

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6 When deciding whether or not to impose a holding limit and if so at which level, financial stability and central bank footprint considerations will of course be only one part of the equation. Other considerations include the usability of a digital euro (e.g. households' average expected transaction size and income) and the digital euro's monetary anchor role, among others.

**The remainder of the paper is structured as follows.** Chapter 2 presents a literature review. Chapter 3 presents the model and Chapter 4 the data and descriptive statistics. Chapter 5 studies the impact on the Eurosystem and banks' balance sheets of a potential digital euro introduction as simulated by our model. Chapter 6 considers variations to the data input and model specifications, including a lower initial level of excess reserves, an imperfect interbank market and a bank run scenario. Chapter 7 sets out the conclusions and policy relevance.

# 2 Literature review

**A growing literature uses theoretical models to study how banks might be impacted by CBDCs.** Serving as a benchmark, Brunnermeier and Niepelt (2019) present an "equivalence" result: under certain conditions, banks would, in theory, be unaffected by a deposit outflow to CBDCs if the central bank were to redirect liquidity back into the banking system under favourable conditions. Our model could replicate the equivalence result by assuming an environment in which central bank funding is the cheapest adjustment option and does not require collateral. However, we focus on the realistic situation when the equivalence result does not hold due to liquidity regulation, collateral requirements and in the absence of unconventional monetary policy instruments. Some of these aspects are also studied by Niepelt (2020), Assenmacher et al. (2021), Burlon et al. (2022), Williamson (2022), and Muñoz and Soons (2023). Our model differs from these studies as it has a focus on liquidity risk and considers the bank level optimization problem rather than the required macroeconomic adjustment.

**Only few papers have attempted to quantify the potential impact of a CBDC on individual banks.** Since no developed country has introduced a CBDC, there is no data available to measure its impact on banks. A small number of papers resort, however, to scenario analyses. Castrén et al. (2022) use a network approach to consider how sector-level balance sheets might change under different CBDC scenarios. BIS (2021) considers a stylised model in which the banking system holds its liquidity ratio constant after deposit outflows by acquiring HQLAs using long-term wholesale funding; however, it makes no allowance for the fact that the availability of reserves in the banking system might be a constraint. Gorelova et al. (2022) considers the impact on liquidity ratios of several large Canadian banks if retail funding were to be replaced by funding with a higher run-off rate, again abstracting from the fact that the overall reserves in the system are not infinite. We add to these studies due to our granular bank-level data and detailed simulation model which simultaneously encompasses liquidity, collateral and reserve constraints at individual bank and banking system level. This makes it possible to consider how individual banks would select their preferred funding option rather than resorting to a stylised sector-level scenario analysis. Gross and Letizia (2023) provide upper bound estimates of actual CBDC take-up, under different assumptions of CBDC renumeration. This nicely complements our analysis, as we are agnostic regarding the actual take-up and rather simulate how banks might respond to different retail deposit outflows. Preliminary and partial results of our analysis featured in Adalid et al. (2022).

# 3 The model

This Chapter sets out the intuition behind the optimisation model. A more detailed technical presentation of the model is contained in Appendix A.

**We model how each bank would optimally respond to a retail deposit outflow while minimising costs and allowing for liquidity, collateral, and reserve constraints.** In the model, banks can intermediate CBDC demand in three ways: 1) by using their current central bank reserves or banknotes, 2) by obtaining additional central bank reserves or banknotes on the interbank market[7], or 3) by increasing central bank borrowing.[8] To be precise, on the asset side of its balance sheet, a bank could accommodate its retail deposit outflows by reducing its existing central bank reserve holdings, thereby also reducing the size of its balance sheet. Should the bank not have sufficient reserves, it could obtain additional central bank reserves on the interbank market or increase its central bank borrowing. The bank would replace retail deposits with wholesale or central bank borrowing on the liability side with no impact on the size of its balance sheet, but its assets would be encumbered if it engaged in secured borrowing.[9] Importantly, the model assumes a perfectly functioning and frictionless interbank market. In Chapter 6, we relax this assumption.

**Not all funding options are equally feasible or desirable given that they would have an impact on banks' profitability, liquidity risk, and collateral availability.** Secured funding is cheaper than unsecured funding and short-term funding is less expensive than long-term funding. Yet, drawing down own reserves or pledging HQLAs as collateral to obtain secured funding negatively impacts banks' liquidity positions (reducing their LCR). Furthermore, using short-term rather than long-term funding increases banks' roll-over risk (reducing their NSFR). With regard to relative prices, we assume that the deposit facility rate provides a floor for interbank market prices and that interbank market funding is cheaper than central bank funding for all banks. This is what could be expected in an economy without an active unconventional monetary policy encompassing instruments such as targeted longer-term refinancing operations (TLTROs).[10] This order of precedence for pricing is assumed to be a constant for the following reason: when banks reach the lower limit

7 Our model does not preclude banks obtaining liquidity from non-banks. If a bank borrows from a non-bank, reserves are transferred from the bank at which the non-bank holds its deposit to the borrowing bank. This lowers the reserves at the non-bank's bank and increases the reserves at the borrowing bank in exactly the same way as if the bank had borrowed directly from the non-bank's bank. In terms of LCR, the impact for both banks is almost the same. However, the LCR of the non-bank's bank is slightly higher when reserves are lent via the non-bank rather than by the bank itself given that the run-off risk of the non-bank no longer exists.

8 There is, in fact, a fourth option, which we do not consider: the bank could sell assets to obtain reserves. The impact of this option on banks' constraints (collateral, LCR, NSFR) is very similar to that of secured wholesale funding.

9 We assume that the central bank provides as much liquidity as demanded through its normal market operations.

10 If we allowed for TLTROs as the cheapest source of funding, all banks would first fully exhaust their TLTRO capacity before resorting to their own reserves. TLTROs would be the most profitable option given their low cost due to the fact that no HQLA collateral needs be pledged, and that there is no negative impact on liquidity risk. In fact, switching from deposit funding to TLTROs would have improved bank profitability since the rates earned would have been below deposit rates.

of their liquidity risk tolerance and become reluctant to provide further liquidity on the interbank market, the Eurosystem would supply additional reserves to avoid stress on the interbank market, thereby ensuring that interbank lending prices do not exceed the relevant policy rates. Consistent with this, in our model, banks obtain funding from the central bank if and only if they become reluctant to lend on the interbank market due to their liquidity risk aversion.

**The model includes constraints at the bank level in terms of liquidity risk, collateral, and reserves, as well as a reserve constraint at the banking-system level.** First, the liquidity risk constraint imposes different voluntary liquidity buffers, depending on the liquidity risk tolerance scenario, as discussed in the next paragraph. The liquidity requirements are the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR). Second, a collateral constraint may be faced given that certain types of secured funding from other banks or the Eurosystem require collateral. We therefore use asset-specific haircuts for secured transactions as specified in the ECB’s collateral framework. Third, with regard to reserve constraints, each bank can only draw down the central bank reserves it actually holds. Furthermore, the banking sector as a whole is constrained by the available reserves in the system. To be clear, if a bank uses reserves to meet a demand for CBDC, irrespective of whether they are its own reserves or those borrowed from another bank on the interbank market, there is a decline in the available reserves in the system as a whole. Furthermore, the liquidity ratios of banks on both sides of the transaction are affected; depending on the type of funding, this may result in a decrease in unencumbered HQLAs, and/or an increase in expected outflows and/or in the required stable funding. If banks were to become reluctant to lend due to liquidity risk considerations, this could lead to upward pressure on interbank rates, making central bank funding more attractive; banks would then resort to the central bank to obtain additional liquidity. An alternative way of thinking about this mechanism is that the central bank would inject further liquidity into the banking system just before market prices started rising sharply.

**Banks face relative, rather than absolute, liquidity risk constraints in our model, reflecting the observed liquidity risk preference heterogeneity in our sample.** In 2021, LCR and NSFR values in the euro area range between just above the regulatory minimum (102%) to more than six times the regulatory minimum (600%). It is likely that banks with high voluntary liquidity buffers would prefer to maintain relatively high buffers following a CBDC introduction, reflecting persistent heterogeneous liquidity preferences. Thus, rather than assuming that all banks would be willing to reduce their liquidity buffer by the same absolute amount, we consider the following three liquidity risk tolerance scenarios: A) banks and markets have a high liquidity risk tolerance and are willing to use and lend reserves until their liquidity ratios hit the regulatory minimum (sustain 0% of their current voluntary buffers), or B) banks and markets have an intermediate liquidity risk appetite and want to keep half of their currently held bank-specific liquidity buffer above the regulatory minimum (sustain 50% of their current voluntary buffers), or C) banks and markets are extremely risk averse and are not willing to make any reduction to their current liquidity buffers (sustain 100% of their current voluntary buffers). Scenario B is our baseline scenario, where a 50% decrease in a voluntary liquidity buffer coincides with the historical median yearly change to individual banks' regulatory liquidity ratios observed since 2016.

# 4 Data and descriptive statistics

**We used regulatory data on 2,319 euro area banks in our model to illustrate how a hypothetical introduction of a digital euro would have impacted the balance sheets of the Eurosystem and of banks in 2021.** In our main analysis, we used data for the third quarter of 2021. Our sample represents 95% of the euro area banking system in terms of total assets. In Chapter 6 we present results based on data for the third quarter of 2019 to gauge the impact of a varying macroeconomic environment combined with lower excess reserves and more available collateral.

**There is considerable heterogeneity among euro area banks in terms of their reliance on retail deposit funding, i.e. their exposure to a deposit outflow, and in terms of their accumulation of cash and reserves, i.e. the ease with which they could cope with a deposit outflow.** In this regard, we distinguish between significant institutions (SIs), which account for 5% of banks but represent 83% of the total assets in our sample, and less significant institutions (LSIs).[11] SIs are grouped by business models according to an ECB Banking Supervision business model classification.[12] Global systemically important banks (G-SIBs) and universal banks together account for more than half of total assets in our sample. Chart 1 illustrates the relative size of each group in our sample.

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[11] LSIs are banks that do not fulfil any of the significance criteria specified in the Single Supervisory Mechanism (SSM) Regulation – significant institutions being those that fulfil at least one such criterion (see e.g. https://www.srb.europa.eu/en/glossary). In practice, the bulk of LSIs are smaller banks whose individual assets do not exceed €30 billion.

[12] Differing from the ECB Banking Supervision classification, and to enhance readability of the charts, we include credit lenders in the retail lenders category and asset managers and custodians in the investment bank category given that we found the impact of digital euro on those types of financial institution to be very similar to bank in the categories concerned. It should be noted that development/promotional lenders are not included in the results in this paper because they are government owned and are likely to behave differently.

**Chart 1**

Relative proportion of bank assets in our sample by business model

(share of total assets)

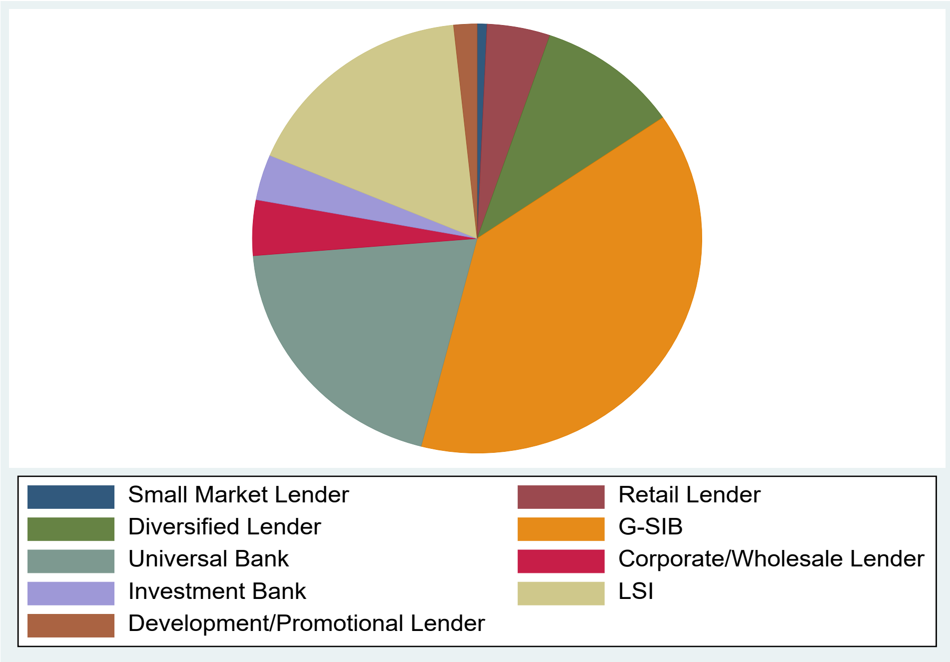



**Chart 2 provides a breakdown, by business model, of banks' reliance on retail deposit funding (panel a) and their accumulation of reserves (panel b).** Small market lenders, retail lenders, diversified lenders and LSIs are particularly reliant on retail deposits: half of banks within these business model categories rely on retail deposits for more than one-third of their funding. In contrast, G-SIBs, universal banks, corporate or wholesale lenders, and investment banks are less reliant on retail deposits. Banks' reserves and banknote holdings are also distributed heterogeneously, although the variation between banks is smaller compared with the variation in the deposits-to-assets ratio. With regard to SIs, the highest reserve-to-asset ratios are to be found among investment banks, universal banks, small market lenders, wholesale lenders, and diversified lenders have the highest reserves-to-assets ratios. LSIs generally hold relatively little reserves and banknotes, given that many are savings banks or cooperative banks. These institutions often organise their liquidity risk management centrally. Their central institutions, which are usually SIs, hold reserves and banknotes on their behalf.

**Chart 2**

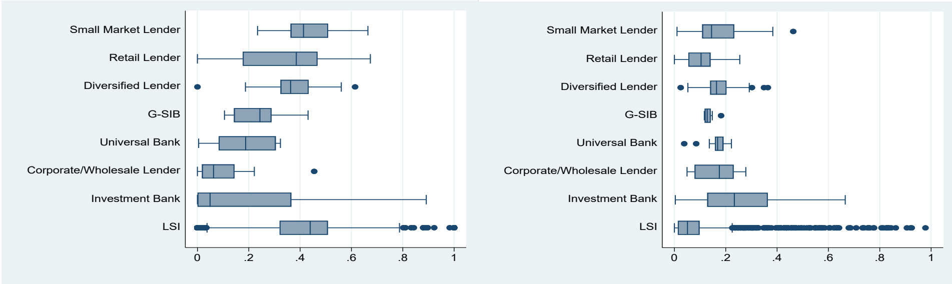
Banks’ disposition and resilience to retail deposit outflows by business model

a) Deposits-to-assets ratios for overnight household deposits

(x-axis: deposit-to-asset ratio)

b) Reserves-to-assets ratios

(x-axis: reserves-to-asset ratio)




Notes: In panel b, banknotes are included in reserves.

**In Chart 3, information on banks’ exposure to deposit outflows and their reserve holdings is combined.** We denote the sum of bank $i$‘s reserve holdings and banknotes by $R_i$ and its retail deposit funding by $D_i$. The maximum percent $\alpha_i$ of retail deposit outflows that a bank can accommodate on its own without turning to the interbank market or the Eurosystem equates to

$$\alpha_i = \min(100\% , \frac{R_i}{D_i})$$

**Chart 3 presents the distribution of $\alpha_i$ in our sample, split between SIs (panel a) and LSIs (panel b).** It shows that many SIs could accommodate an outflow of all their retail deposits. More than 90% of SIs and 40% of LSIs could deal with an outflow of 20% of their retail deposits on their own, whereas the rest would need to resort to the interbank market or the central bank to obtain additional reserves. As indicated above, savings banks and cooperative banks, which make up a large share of LSIs, would naturally resort to their central institution to obtain additional reserves.

**Chart 3**

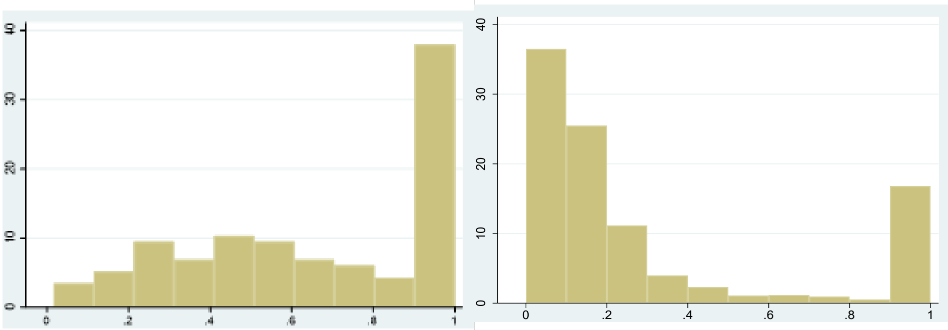
Proportion of banks able to fund retail deposit outflows into digital euro on their own

a) Significant institutions

(x-axis: $\alpha\%$ of overnight deposit outflow)
(y-axis: percentages of total banks)

b) Less significant institutions

(x-axis: $\alpha\%$ of overnight deposit outflow)
(y-axis: percentages of total banks)



**Banks would not, however, rely solely on their own reserves to accommodate deposit outflows into a digital euro.** Banks could obtain additional reserves from the interbank market or from the Eurosystem's regular open market operations.

# 5 Simulation results

In this Chapter, we set out the simulation results of our detailed model encompassing a multitude of adjustment options aimed at analysing how banks might respond to retail deposit outflows and to determine what the ensuing balance-sheet implications might be.

**Our study took no account of the design of a future digital euro, nor did it estimate the demand for a CBDC; instead it simulates how banks might respond to different retail deposit outflows.** We focus on retail deposits, given that we consider these to be the most likely form of private money to be converted on demand into central bank money (also see Adalid et al., 2022). We simulate the impact of a range of deposit outflows but do not consider the probability of any given deposit outflow. For illustrative purposes, we assume that each bank would lose the same proportion of its retail deposits. Consequently, banks holding more deposits would experience a greater depletion of their retail deposits in absolute terms. There are, however, grounds for believing that banks with more digital affine customers, smaller individual retail deposits or lower deposit rates might be disproportionately affected. Banks might also raise their deposit rates or improve customer services in response to deposit outflows. While such factors can be included in our model, they fell outside the scope of this paper.

**Based on the holding limit postulated, we consider that a deposit outflow of €1.0 trillion, translating into a 15% aggregate retail deposit outflow in the third quarter of 2021, would be the most extreme outflow.** The ultimate design of a digital euro remains uncertain. However, an unlimited supply of digital euro seems unlikely and the possibility of a €3,000 holding limit per person has been suggested (Bindseil and Panetta, 2020). Multiplying the €3,000 limit by the euro area population of 340 million gives a maximum aggregate outflow of €1.0 trillion, which would be reached if each bank had converted 15% of its retail deposits into digital euros in the third quarter of 2021. In practice, it is highly unlikely that all euro area residents would always fully exhaust the holding limit; it is also doubtful whether they would all have sufficient savings to do so. In addition, it is likely that residents would not only convert their retail deposits into digital euros but also some of their banknotes. In essence, we would expect less (and probably much less) than 15% of retail deposits to be transformed into digital euro if a €3,000 limit were to be put in place. The 15% retail deposit outflow is indicated by a shaded area in the charts below.

**The simulation quantified the impact on the balance sheets of the Eurosystem and banks for different liquidity risk tolerance scenarios and different levels of deposit outflows.** We analyse the impact under three liquidity risk tolerance scenarios as outlined in the previous Chapter.[13] We determine for each of the

[13] Under Scenario A, banks have a high liquidity risk tolerance and are willing to use and lend reserves until their liquidity ratios hit the regulatory minimum. Under Scenario B, our baseline scenario, banks have an intermediate liquidity risk appetite and wished to keep half of the bank-specific voluntary liquidity buffers they held in excess of the regulatory minimum. Under Scenario C, banks are extremely risk averse and not willing to make any reduction to their voluntary liquidity buffers.

liquidity risk tolerance scenarios and levels of deposit outflows, the type of interbank funding banks would choose: short term or long term, secured or unsecured. We also determine when banks would be reluctant to provide further reserves on the interbank market, calling for more liquidity to be supplied by the Eurosystem. With regard to the latter, we also establish whether or not banks would have sufficient currently eligible collateral to obtain such funding for a given level of deposit outflow. Finally, we investigate which banking groups would experience extreme changes in their funding structures, in particular as a result of relying on wholesale and central bank funding, as compared with their historical changes in funding.

## 5.1 The impact on the Eurosystem balance sheet

**We first study when, how much and which type of central bank funding banks would need in order to keep to their preferred liquidity buffers.** Wholesale funding is generally cheaper than central bank funding, whether short term or longer term. Consequently, individual banks do not resort to the Eurosystem for additional reserves if there is sufficient liquidity on the interbank market.

**Chart 4 shows the composition of the aggregate central bank funding that would be required to ensure that banks would operate within a given liquidity risk tolerance scenario.** When deposit outflows would have exceeded 20% in our baseline liquidity risk tolerance Scenario B, or 40% under Scenario A, banks become reluctant to lend on the interbank market. Before this reluctance would lead to rising market prices, the Eurosystem would be likely to provide additional liquidity to banks. Banks would choose between short-term and long-term central bank funding secured by HQLA collateral, long-term central bank funding secured by eligible non-HQLA collateral and central bank funding secured by currently non-eligible collateral. Eligible non-HQLA collateral includes credit claims which are non-marketable assets and which are therefore not tradable on the interbank market in our model. We use the face value of unsecured eligible collateral as reported by banks to distinguish between central bank funding secured by eligible and non-eligible collateral. This measure disregards the mandatory haircut on eligible non-HQLA collateral and results in an underestimation of the amount of central bank funding secured by currently non-eligible collateral.

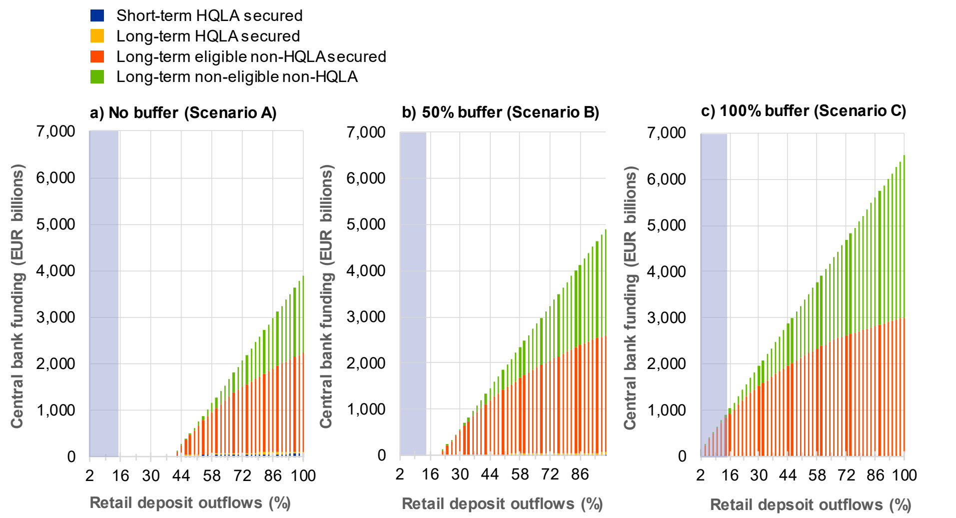
**In our simulation, banks primarily use non-HQLA collateral to obtain additional reserves from the Eurosystem.** Since we assume that secured interbank funding would be cheaper than secured central bank funding, banks would use most of the HQLAs they hold in excess of their assumed preferred voluntary liquidity buffers to obtain secured funding on the interbank market. Should the interbank market start to dry-up, there would be few HQLAs left to be used as collateral for central bank funding. Instead, banks would secure their central bank funding using eligible non-HQLA collateral to sustain their preferred liquidity buffers.[14]

[14] It should be noted that a small amount of HQLA-secured lending would be possible in our simulation even if banks were to hit their LCR constraint given that the LCR denominator decreases when additional retail deposits are withdrawn, making it possible for some HQLAs to be encumbered before the LCR constraint again becomes binding.

**Even with the most extreme outflows, banks would not have required additional reserves from the Eurosystem if they wished to sustain half of their voluntary liquidity buffers.** Chart 4 shows that with a €3,000 holding limit, the Eurosystem would not have needed to supply additional reserves under our baseline scenario. Under Scenario C, banks are willing to provide almost no liquidity on the interbank market because they want to keep their liquidity ratios high (panel a). Banks would then require large amounts of central bank funding. The most extreme outflow would result in an increase in the size of the Eurosystem balance sheet of approximately €1.0 trillion. This compares with an Eurosystem balance sheet in the third quarter of 2021 of approximately €8.5 trillion in assets and liabilities. Most banks would, however, have had sufficient eligible collateral under worst-case outflows to obtain their desired level of funding. We find that, in Scenario C, it was only when outflows exceed 16% that more than 10% of the longer-term central bank funding required would be sought against non-eligible collateral. This assumes that no eligible non-HQLA collateral is traded on the interbank market.[15]

### Chart 4

Additional central bank reserves required for an orderly digital euro introduction




Notes: The shaded area represents the possible share of deposit outflows in the event of a €3,000 holding limit.

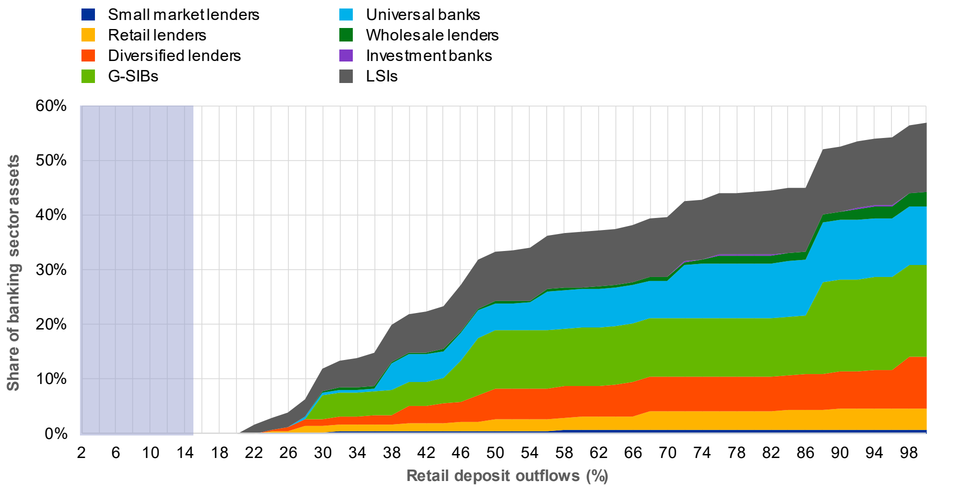
**Should the outflows be unrealistically high, some banks might not have sufficient currently eligible collateral to obtain the reserves required to keep to their preferred liquidity buffers.** Chart 5 shows a business model breakdown of the proportion of the banking sector's total assets that are held by banks with insufficient eligible collateral in the third quarter of 2021 to obtain the central bank funding they would have needed to keep half of their voluntary liquidity buffers. In our sample, we find that when outflows would be unrealistically high, LSIs would be the first to run out of currently eligible collateral, followed by diversified and retail lenders. Based on our simulations, if outflows would have exceeded 28% – almost double the worst-

[15] Figure B.1 in Appendix B allows for eligible non-HQLA collateral to be traded on the interbank market. Where this is the case, 10% of the longer-term central bank funding required would be sought against non-eligible collateral only if deposit outflows exceeded 70%.

case outflow – the first G-SIB would have had insufficient collateral to obtain the funding it required.

**Chart 5**

Share of total banking sector assets of banks with insufficient eligible collateral for central bank funding for a given proportion of retail deposit outflows – Scenario B




Notes: The shaded area represents the possible share of deposit outflows in the event of a €3,000 holding limit.

## 5.2 The impact on banks' balance sheets

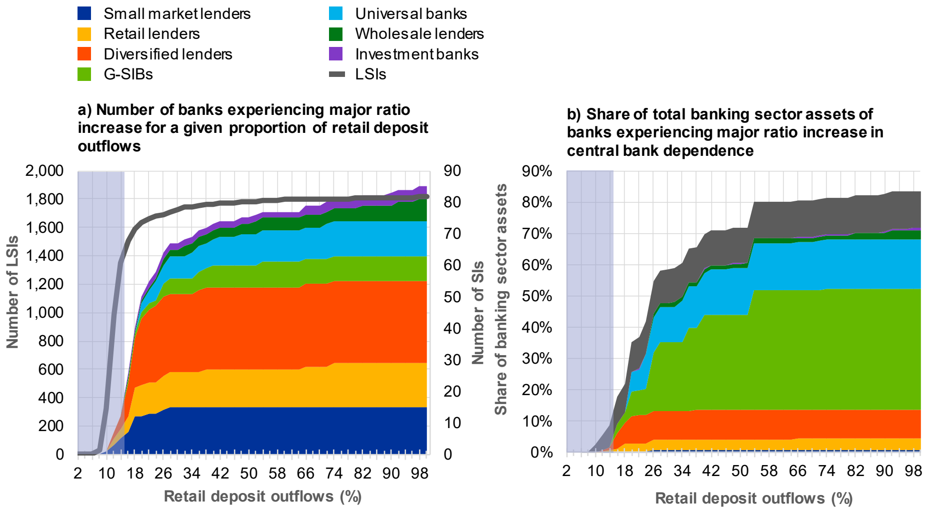
### 5.2.1 Central bank reliance

**We next investigate if, and when, the substitution of central bank funding for retail deposits would have led to unusually high levels of, or large increases in, banks' central bank reliance.** A high level of, or extreme increase in, central bank reliance would not, per se, present a risk for the banking sector given that central bank funding is a stable form of funding. Excessive reliance would, however, expose the Eurosystem to counterparty and market risks, and might undermine desirable market dynamics and discipline. On aggregate, small market and retail lenders in particular, but also diversified lenders and LSIs, would be the most reliant on the Eurosystem, see Chart B.2 in Appendix B. Yet, the greater central bank reliance simulated for LSIs in the event of a 15% deposit outflow would still be lower, on aggregate, than the central bank reliance observed among diversified lenders in the third quarter of 2021.

**As regards changes in central bank reliance, we first consider Scenario C, in which central bank dependence would increase the most with banks maintaining their high voluntary liquidity buffers.** Chart 6 shows the number of banks and the percentage of the banking system, in terms of total assets, for which an increase in central bank funding would be exceptionally high as compared with the median quarterly increases in central bank funding of their peers observed since 2016. If the banking sector would be unwilling to see any increase whatsoever in liquidity risk and instead relies on central bank funding, less than 10% of the banking sector would experience an unusually high increase in central bank reliance in the event of the worst-case outflow of 15%. The vast majority of banks that would experience an unusual increase in central bank reliance would be LSIs. It should be noted, however, that LSIs have seen relatively low increases in central bank reliance in the past, hence even small increases in that reliance are considered unusual.

## Chart 6

Significant changes in central bank funding ratios under Scenario C for a given proportion of retail deposit outflows



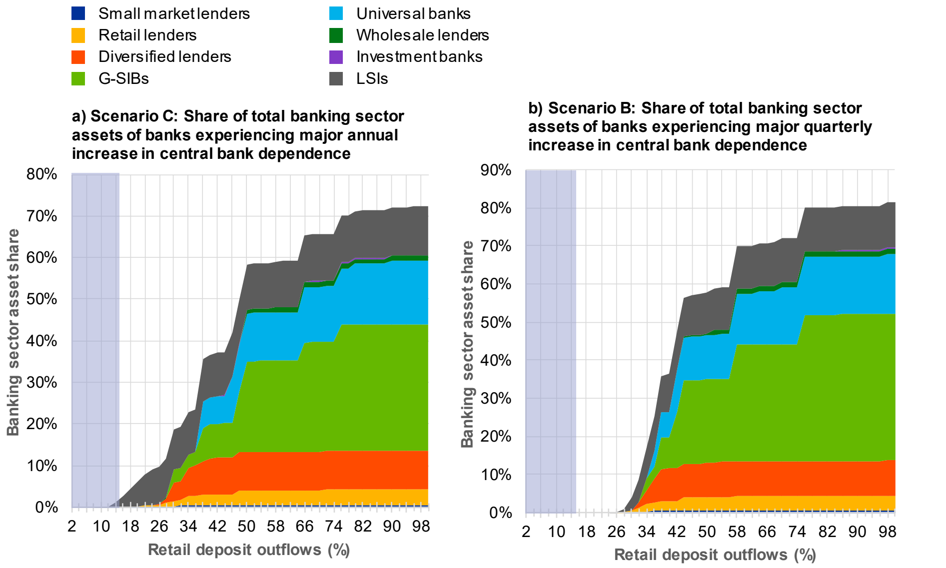

Notes: Major ratio increases are those changes which are above the 90th percentile of quarterly central bank funding ratio increases observed since 2016 for SIs and LSIs respectively. In panel a, the left-axis shows the number of LSIs and the right-axis the number of SIs per business model. The shaded area represents the possible outflows in the event of a €3,000 holding limit.

**A slow introduction, over at least a year, would render any changes to central bank reliance less extreme.** Unsurprisingly, banks have, in the past, seen larger increases in central bank reliance over a year than over a single quarter. If the digital euro was phased in over a year (Chart 7a), the increase in the central bank funding ratio would only become extreme for more than 10% of the banking system if more than 28% of retail deposits were to be converted into digital euros.

**Under baseline Scenario B, central bank reliance would only become extreme for a material proportion of the banking system if more than 32% of retail deposits were withdrawn, an unrealistic outflow for a digital euro.** The results presented in Chart 6 are based on Scenario C and thus represent a worst-case scenario in terms central bank dependence. A less extreme outcome is obtained under the baseline scenario, Scenario B, in which banks are willing to reduce their high liquidity buffers by half. As can be seen from Chart 7b, under Scenario B, increases in central bank funding would become more extreme as compared with historical median quarterly ratio changes only if more than 32% of retail deposits were withdrawn. This is due to the fact that banks turn to interbank lending before resorting to central bank funding.

**Chart 7**

Significant changes in central bank funding ratios for less extreme scenarios




Notes: Major ratio increases are those changes which are above the 90th percentile of yearly (panel a) and quarterly (panel b) central bank funding ratio increases observed since 2016 for SIs and LSIs respectively. The shaded area represents the possible outflows in the event of a €3,000 holding limit.

## 5.2.2 Wholesale funding reliance

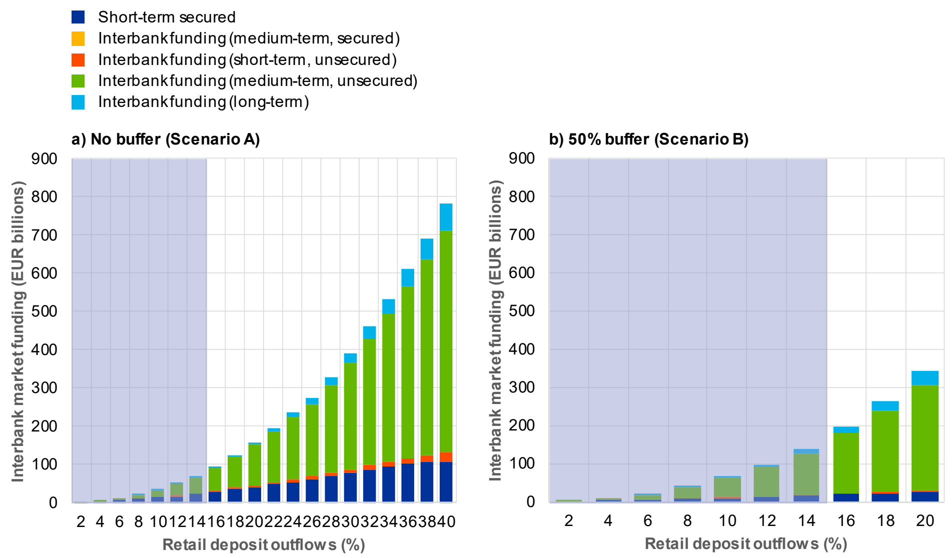
**Whether banks choose to act as a borrower or lender on the interbank market depends on their reserves and deposit holdings, as well as on their liquidity preferences.** Unsurprisingly, interbank market lenders tend to be those banks with a relatively low reliance on retail deposits and with large reserves, such as investment banks and wholesale lenders. On the other hand, G-SIBs and LSIs are the largest absorbers of wholesale funding (which includes liquidity flows from central institutions to affiliated savings or cooperative banks), see Chart B.2 in Appendix B.

**In our model, the type of interbank funding opted for is determined by the borrower's liquidity risk tolerance and collateral availability, as well as by the relative prices of those options.** Based on each bank's balance sheet, our constraint optimisation model reveals which banks would have increased their secured wholesale borrowing and which would have had insufficient collateral and would therefore have needed to rely on more expensive unsecured loans. Depending on their NSFR, some banks would have needed to increase their long-term wholesale borrowing, while others would have been able to rely on cheaper short-term borrowing.

**The largest share of interbank funding is simulated to be unsecured with medium-term maturity, such as commercial paper with 3-6-months maturity.** Chart 8 shows the aggregated volumes of different types of interbank funding for a range of deposit outflows. Panel a shows the various types of interbank funding opted for by banks with a relatively high liquidity risk tolerance and that use their entire liquidity buffer above the regulatory minimum (Scenario A), while panel b shows interbank funding for our baseline scenario, Scenario B.[16] Banks prefer secured short-term funding given that this is the cheapest type of interbank funding. However, this increases banks' liquidity risk and hence negatively affects their LCRs and NSFRs. In the light of this, the largest share of interbank funding would be unsecured debt with a medium-term maturity (such as commercial paper with a maturity of 3 to 6 months), given that this is the cheapest source of funding that does not negatively affect a bank's LCRs. Banks would, however, need to resort to more expensive long-term funding to sustain their NSFR buffers should too many retail deposits, which count towards stable funding, be withdrawn. For example, our simulations show that under our baseline scenario, Scenario B, and based on data for the third quarter of 2021, 82% of the most extreme deposit outflow of 15%, equating to €1.0 trillion, would have been replaced, on aggregate, by own reserves (not shown in Chart 8), 14% by medium-term unsecured interbank funding and only 2% by short-term secured funding and 1% by long-term unsecured funding.

**Chart 8**

Simulated interbank market funding for a given proportion of retail deposit outflows




Notes: The data used for this simulation were those for the third quarter of 2021. The shaded area represents the possible outflows in the event of a €3,000 holding limit.

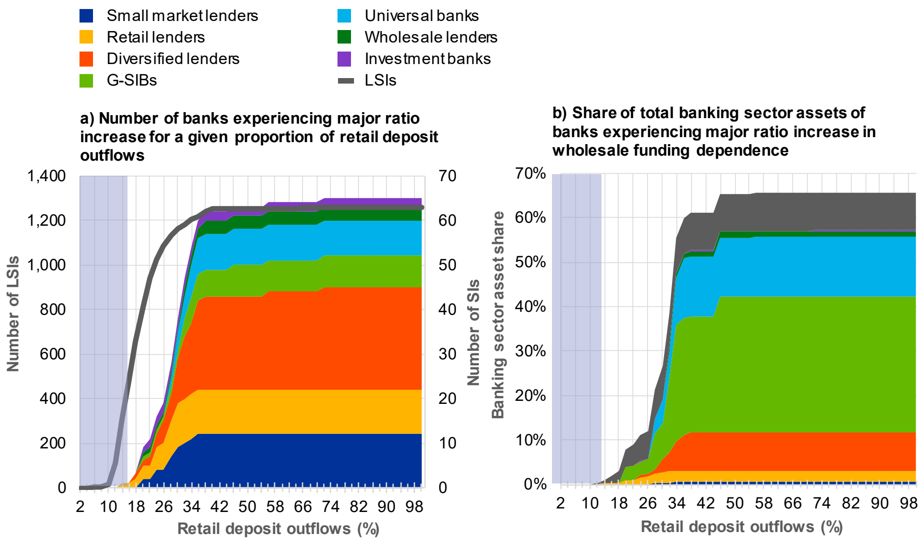
**Even with the most extreme deposit outflows, unusual increases in wholesale funding reliance would be rare, including under Scenario A in which banks have maximum recourse to interbank lending without breaching their liquidity requirements.** The funding structures of banks that are net borrowers on the interbank market would shift from retail deposits to wholesale funding. Chart 9 shows the number and asset share of banks that would experience exceptionally high increases in their wholesale funding ratio under Scenario A as compared with the 90th percentile of quarterly increases in wholesale funding ratios of their peers observed since 2016. We found that the number of LSIs with an unusual increase in their wholesale funding ratio would rise sharply if more than 10% of retail deposits would have been withdrawn. Such banks would, however, account for just a small

16 Scenario C is omitted given that there is almost no interbank lending.

proportion of total banking sector assets. It would be only when outflows are unrealistically large and exceed 20% of retail deposits that a first steep increase would be seen in the proportion of banks, in terms of total banking sector assets, with an unusual increase in their wholesale funding ratio; this was due to the impact of a single G-SIB and of some of the larger retail banks. It is not until deposit outflows exceed 24% of retail deposits, or €1.6 trillion, that banks representing 10% of total banking sector assets would experience a significant increase in their wholesale funding ratios.[17] Given that the bulk of retail deposits would be replaced by medium-term unsecured funding, the short-term liquidity risk would not increase, although banks' funding structures would become less stable over a longer time-horizon. It should be stressed that the increase in liquidity risk which is usually associated with an increase in wholesale funding is constraint by our bank liquidity risk tolerance assumption.

**Chart 9**

Significant changes in wholesale funding ratios for a given proportion of retail deposit outflows - Scenario A




Notes: Major ratio increases are those changes which are above the 90th percentile of quarterly wholesale funding ratio increases observed since 2016 for SIs and LSIs respectively. Central bank funding is excluded from the wholesale funding ratio. The shaded area represents the possible outflows in the event of a €3,000 holding limit.

**With regard to the baseline scenario, or in the event of a longer digital euro introduction phase, wholesale funding ratio increases would not be a source of concern, even with unrealistically high deposit outflows.** Chart 9 presents an extreme scenario in terms of the impact on wholesale funding for two reasons. First, the ratios are simulated for Scenario A, in which banks use their entire liquidity buffer above the regulatory minimum. It is, however, much more likely that banks would not willingly engage in interbank lending and borrowing to this extent and the impact on wholesale funding would therefore be lower (while the impact on central bank

17 With lower outflows, deposit funding would be partially substituted for by wholesale funding, and wholesale funding ratios would increase. If the interbank market ran out of liquidity, additional deposit outflows would primarily be substituted for by central bank funding, although deposit outflows would also free up required reserves, which could then be used to meet the demand for digital euro; this would decrease total assets, while wholesale funding would remain constant. Consequently, wholesale funding ratios would continue to increase slightly even if there was no additional interbank funding.

funding would be higher). Under our baseline scenario, Scenario B, banks could lose more than half of their retail deposits before banks representing more than 10% of total banking sector assets would experience an extreme increase in their wholesale funding ratios (see panel b of Chart B.4 in Appendix B). Second, the simulated wholesale funding ratio changes are compared with the historical increases over a single quarter. If the simulated increases are compared with the historical increases over one year, the increase in wholesale funding is extreme solely for LSIs (see Chart B.4, panel a, in Appendix B).

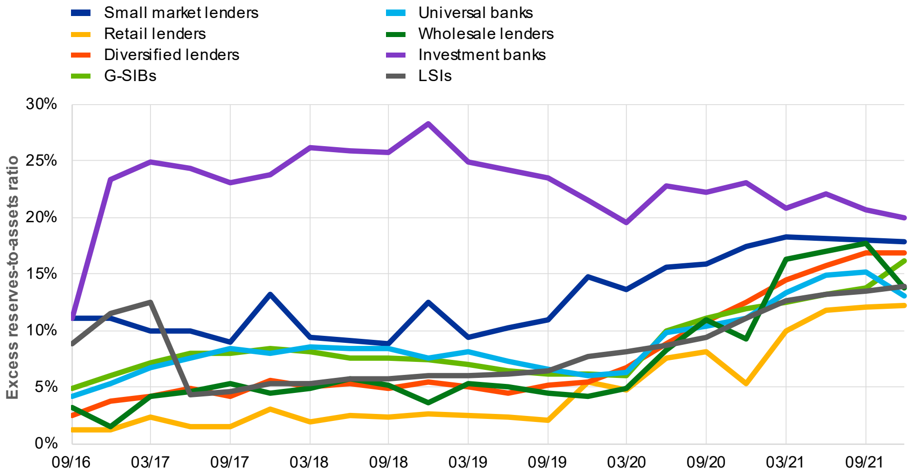
# 6 Alternative model specifications

## 6.1 An environment with lower excess reserves

**The simulation results presented in the previous Chapter are based on data for the third quarter of 2021, a high reserve environment.** Since the start of the pandemic in March 2020, the ratio of central bank reserves to total banking sector assets has increased to an exceptionally high level, as shown in Chart 10, which goes hand in hand with lower available collateral. The results in Chapter 5 were based on these high reserve ratios.

**Chart 10**

Historical changes in banks' excess reserves-to-assets ratio




**To assess the impact of a digital euro in a lower reserve environment, we repeat our analysis using data for the third quarter of 2019 to reflect that the level of reserves in the banking system might be lower if, and when, a digital euro is introduced.** It is impossible to anticipate how each bank's balance sheet would adjust to any future normalisation of reserves or the policies or regulations that would accompany that normalisation. In the third quarter of 2019 the aggregate reserve ratio was around 6%, whereas it was close to 14% in the third quarter of 2021 (see Chart 10). The period selected (the third quarter of 2019) is as far back as we could go due to data availability and to the evolving regulatory environment. Also, the period predated the restarting of the Asset Purchasing Programme (1 November 2019), after which the excess reserve ratio started to increase. It is also after the LCR requirement was fully phased in (1 January 2018), but before the NSFR requirement was phased in. Thus, to facilitate comparison with Chapter 5, we assume in the simulation model that the NSFR constraint is not a binding for those banks that did not meet that requirement.[18]

**The data for the third quarter of 2019 showed that banks would have required additional central bank reserves already at a lower deposit outflow.** Naturally, with lower reserves the banking system could only accommodate a lower proportion of deposit outflows without obtaining additional central bank reserves if they were to sustain their preferred liquidity levels. In Chapter 5, we stated that if banks sustain their regulatory minimum liquidity buffers (Scenario A), the banking system could accommodate 40% of deposit outflows without resorting to central bank funding and 20% if they retained half of their current voluntary buffer (Scenario B). The data for the third quarter of 2019 showed that those deposit outflow percentages would have fallen to 20% and 12% respectively. In the third quarter of 2019, a 12% deposit outflow would have equated to €0.7 trillion. Consequently, banks, in 2019, would have required additional reserves from the Eurosystem in the event of the most extreme outflow under Scenario B.

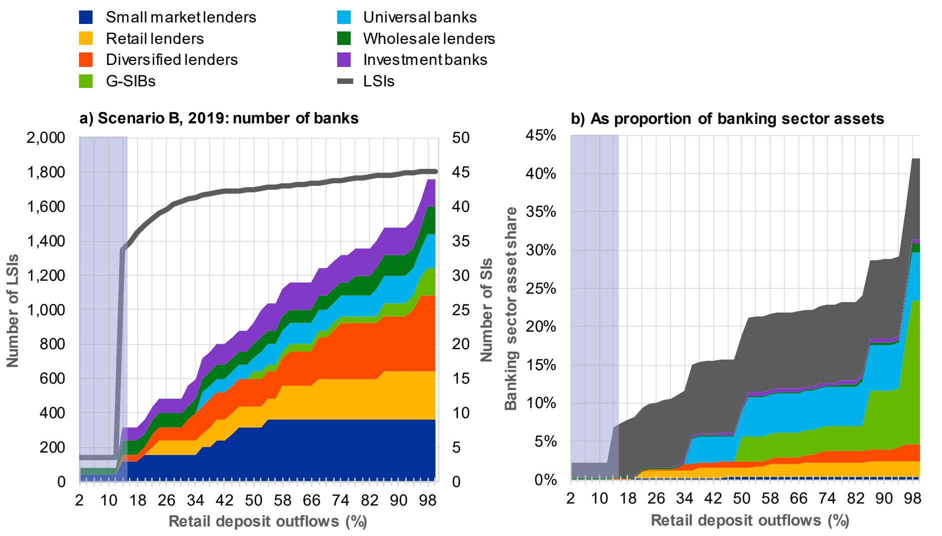
**Based on the data for the third quarter of 2019, most banks would have had sufficient eligible collateral to obtain the additional reserves required from the Eurosystem for the most extreme outflows.** While banks held less reserves in the third quarter of 2019, they had also pledged less collateral with the Eurosystem and sold less of their collateral in quantitative easing programs. Almost all banks had enough eligible collateral to obtain the additional reserves that would have been required for the most extreme outflows of 15%. Chart 14 (in Chapter 7) shows that more than 10% of the banking sector would have required central bank funding secured by currently non-eligible collateral in the third quarter of 2019 only if the outflows had exceeded 38% (and eligible collateral had not been traded on the interbank market).

**Also based on the data for the third quarter of 2019, the impact on banks' funding structures would have been contained.** The increases in the wholesale funding ratios is smaller with lower excess reserves in the system given that there are fewer banks willing, or able, to provide liquidity on the interbank market. The impact on central bank funding reliance would also have been of no concern when compared with historical values. Although banks would have required central bank funding at a lower deposit outflow, they had a lower level of central bank funding dependence to start with. Applying Scenario B to the 2019 data, it would only have been if the outflow exceeded 26% of retail deposits – equating to €1.5 trillion and therefore significantly more than the most extreme outflow of €1.0 trillion – that over 10% of the banking sector would have had central bank funding ratios higher than the highest ratio value observed since 2016 (see Chart 11).

18 Due to this assumption, we underestimate the reliance on long-term interbank market and central bank funding relative to short-term funding. As little use is made of long-term interbank market funding (see Figure 8), this assumption is likely to have only a small impact on our results.

**Chart 11**

Banks with simulated central bank funding ratio higher than their own highest observed ratio since 2016




Notes: In panel a, the left-axis shows the number of LSIs and the right-axis the number of SIs per business model. The shaded area represents the possible outflows in the event of a €3,000 holding limit.

## 6.2 An interbank market segmented across national borders

**It is well documented that most banks predominantly lend to banks located in the same country when economic uncertainty is high, even in the euro area.** In Chapter 5, we consider a digital euro introduction with a perfect interbank market, i.e. banks are willing to lend to any other bank in our sample, irrespective of where they are established, provided that this does not increase their liquidity risk beyond their preferred levels. In this Chapter, we introduce an additional constraint, namely that banks would only be willing to lend to banks located in the same country.

**We find that under our baseline scenario, Scenario B, the banking sector in all euro area countries could accommodate the most extreme outflow without requiring additional central bank reserves.** Table B.1 in Appendix B shows that in the third quarter of 2021 there was considerable heterogeneity in the amount of excess reserves and reliance on deposit funding within the national banking sectors. Banks in some countries (for instance, Belgium, Ireland, Portugal and Finland) were better positioned to accommodate digital euro demand without requiring additional central bank funding as compared with banks in other countries (for instance, Germany, Greece, Spain and Italy). The banking sector of all euro area countries could have, however, accommodated the most extreme outflow of 15%. The banking systems in Belgium, Cyprus and Luxembourg even had sufficient reserves to accommodate the outflow of all retail deposits within their country without banks breaching their liquidity requirements.

**Changes to banks' funding structures and their liquidity risks would also have been moderate if interbank markets had been segmented.** Table 2.A summarises the key take-aways, showing that in the event of the worst-case deposit outflow of 15%, the immediate changes to banks' balance sheets would not be extreme for the vast majority of the banking sector. In addition, there would have been almost no difference in the overall amount of additional reserves banks would require, on aggregate, to keep half of their voluntary liquidity buffers, as shown in Chart 14 in Chapter 7.

## 6.3 A retail bank run scenario

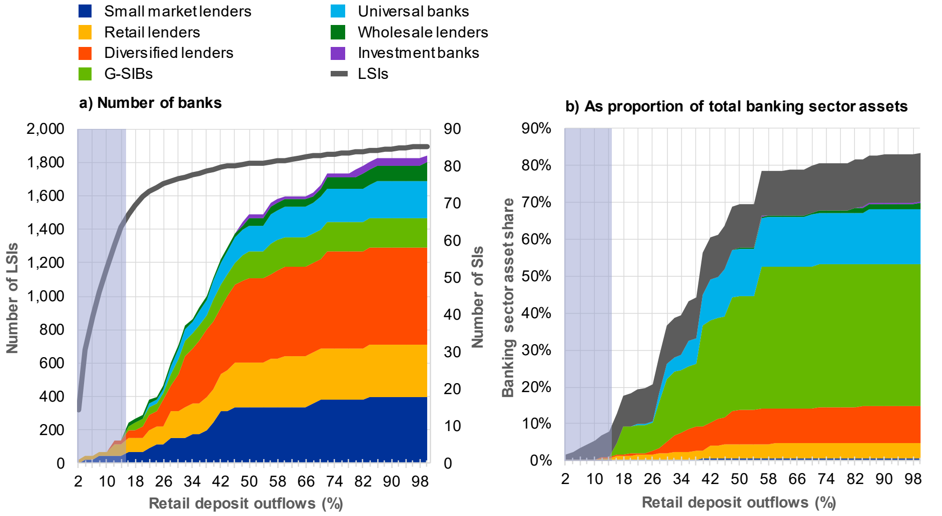
**Our model can also be used to study the impact of a withdrawal of retail deposits during a bank run, regardless of whether deposits are withdrawn to hold banknotes or digital euros.** To be clear, we do not suggest that a bank run would be caused by the potential introduction of a digital euro. Rather, our model could be used to study the point at which a sudden and rapid outflow of retail deposits would lead to liquidity risks, regardless of what has caused the outflows. Compared to outflows into banknotes, one advantage of a digital euro is that, in the event of a bank run into CBDC, a holding limit would limit the maximum possible withdrawal of deposits for the purpose of holding digital euros. A second advantage is that a rapid increase in digital euro demand could be observed by the Eurosystem in real-time so that it could provide the necessary liquidity to the system in due time, to avoid interbank market stress (see Keister and Monnet, 2022).

**In this alternative model specification, we assume that a bank subject to a run would be unable to obtain reserves from other banks and could only accommodate deposit outflows while it still has excess reserves or eligible collateral.** Starting from the model specification used in Chapter 5, we removed the possibility of banks to obtain interbank funding. This means that we assume that no other bank would be willing to lend to a bank experiencing a bank run. We also drop the LCR and NSRF constraints in the constraint optimisation problem given that regulatory buffers are meant to be used when needed. For the sake of illustration, we also include the unrealistic assumption that such banks could not obtain non-HQLA secured central bank funding while they still hold reserves or HQLA collateral. Under these assumptions, the constraint optimisation would simplify to the following bank response during a bank run: a bank would first use all its reserves to satisfy deposit outflows without sustaining its regulatory or voluntary liquidity buffers. Once the bank has fully depleted these, it would obtain the remaining reserves from the Eurosystem, either through normal market operations if it has eligible collateral or via emergency liquidity assistance (ELA). If the bank is unable to obtain reserves to facilitate deposit outflows, it would be illiquid. It should be noted that we consider an extreme scenario in which it is assumed that LSIs would be unable to access any liquidity they might have stored elsewhere, e.g. with their central institution in case of savings and cooperative banks.

**Applying our model to data for the third quarter of 2021, we find that during a bank run a €3,000 holding limit would have curbed banks' liquidity risk if the outflows would be solely for the purpose of holding digital euro.** Liquidity buffers are there to be used during crisis. Consequently, a breach in liquidity ratios would not be a major concern, but would indicate elevated liquidity risk. Chart 12 shows the number of banks which would breach the LCR or NSFR requirement for a given bank-specific retail deposit outflow (panel a), and the proportion of the banking system which they would represent (panel b). During a bank run entailing a fairly low retail outflow, only relatively small LSIs would breach their liquidity requirements. This reflects the fact that LSIs do not generally hold large reserves directly, but often hold liquidity at a central institution. Only a retail deposit outflow of 16% or more would result in a breach of liquidity requirements for a more significant proportion of the banking system, including three G-SIBs. While we do not have the depositor-level data that would be needed to determine the maximum deposit outflow into digital euro for each individual bank in the event that all its depositors were to make use of their €3,000 holding limit, a 15% deposit outflow, as discussed in Chapter 5, could still serve as a benchmark.[19] Based on this benchmark, we conclude that a €3,000 holding limit would contain liquidity risks stemming from outflows into digital euro for the lion's share of the banking sector. Obviously, retail depositors could still withdraw their deposits by transferring money to another bank account or by obtaining stablecoins or banknotes, as is the case today.

### Chart 12

Banks breaching at least one liquidity requirement (LCR or NSFR) for a given proportion of deposit outflow




Notes In panel a, the left-axis shows the number of LSIs and the right-axis the number of SIs per business model. The shaded area represents the possible outflows in the event of a €3,000 holding limit.

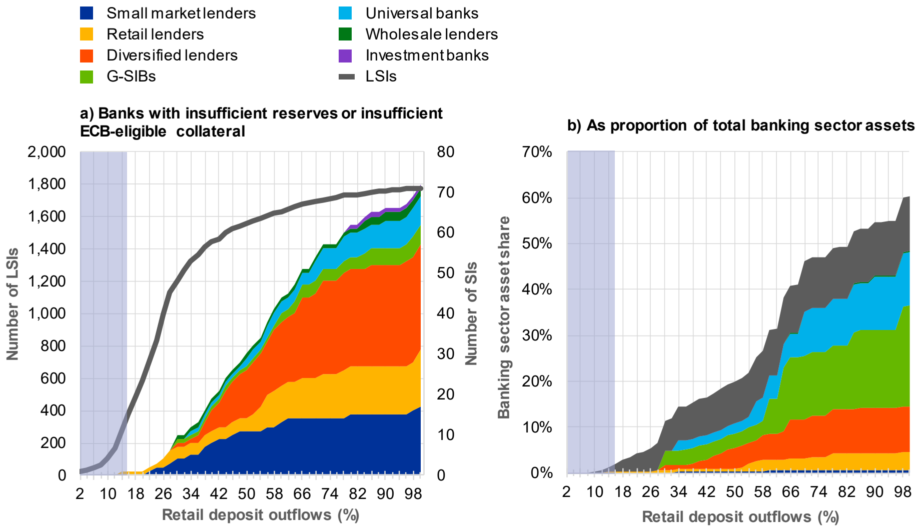
**We also assess the outflows during a bank run that would result in banks needing ELA unless they could obtain reserves from their affiliated central institutions.** During a bank run, banks without sufficient reserves and without sufficient eligible collateral to meet deposit withdrawals could fail unless they could secure reserves from an affiliated central institution or obtain ELA from the Eurosystem. Chart 13 shows the number of banks that did not have sufficient reserves in in the third quarter of 2021 to meet a given outflow of retail deposits and,

19 For comparison, the banking sector in Greece, in 2015, and Cyprus, in 2013, experienced a retail deposit outflow around 20%.

at the same time, did not have sufficient eligible collateral (panel a), and also indicates the proportion of total banking sector assets they represented (panel b), distinguishing between different business models. Almost no banks would have required ELA during a bank run for outflows of less than 15%. Thus, we conclude that with a €3,000 holding limit it would have been unlikely that banks would have become illiquid in the event of a bank run into digital euro.

**Chart 13**

Banks requiring emergency liquidity assistance for a given proportion of deposit outflows




Notes In panel a, the left-axis shows the number of LSIs and the right-axis the number of SIs per business model. The shaded area represents the possible outflows in the event of a €3,000 holding limit.

# 7 Conclusion

**We established a constraint optimisation model to study the impact of a CBDC on banks' funding structures and the demand for central bank reserves given liquidity risk considerations.** The model allows individual banks to endogenously select their preferred balance-sheet adjustments to a retail deposit outflow based on cost-efficiency and given their and their peers bank-specific liquidity preferences, reserve constraints and collateral availability.

**We use the model to illustrate the impact of a fictitious introduction of a digital euro in the third quarter of 2021.** We use granular balance-sheet data for more than 2,000 banks in the euro area to simulate how banks would have restructured their balance sheets and how much additional reserve demand the Eurosystem could have expected for different levels of digital euro uptake and liquidity risk tolerance.

**The simulation suggests that with a €3,000 digital euro holding limit per person, the changes to banks' funding structures and their liquidity risks would have been moderate, and no additional central bank funding would have been needed.** Our simulation results are summarised in Table 2.A, Table 2.B and Chart 14. Our findings are consistent with Mr. Panetta's statement of 15 June 2022 to the European Parliament to the effect that digital euros amounting to a total of between €1.0 to €1.5 trillion would not have negative effects for the financial system, which allows for holdings of around €3,000 to €4,000 per capita (Panetta, 2022).

**We illustrate that the simulated impact would depend non-trivially on the prevailing macroeconomic environment and that the model could also be used for the calibration of holding limits to contain liquidity risks in the event of a bank run into digital euro.** Applying the model to balance-sheet data for 2019, when reserves were less ample, shows a benign impact on banks very similar to that for the baseline analysis. This may, at first, seem surprising but it is due the fact that although banks had lower reserves than in 2021, they held more ECB-eligible assets that could be used to obtain any reserves needed and also had lower retail deposits. Limiting banks to just using their national interbank market, we find that banking sectors in all euro area countries had sufficient liquidity to meet demand for a digital euro. Finally, we showed that our model and data could be used to assess the suitability of CBDC holding limits to contain liquidity risks in the event of a bank run into digital euro. With a €3,000 holding limit it would have been unlikely that banks would have become illiquid in the event of a bank run into digital euro.

**Re-running our model at the time of a potential digital euro introduction could help in assessing whether the timing and the holding limit envisaged are prudent.** The results obtained from our simulation cannot be used to predict the response of banks if a digital euro is, in fact, introduced, given that balance sheets are likely to change in the meantime, including in anticipation of any such event. Nevertheless, it is reassuring to know that any digital euro introduction combined with the suggested limit of €3,000 would have been unlikely to have caused unusual changes in banks' balance sheets and liquidity risks in the periods and under the specifications studied, which included a period with lower excess reserves and also extended to a segmented interbank market. At the time of any digital euro introduction, re-running our model could provide useful insights into the heterogeneous impact of that CBDC across banks and EMU Member States and for the calibration of a digital euro holding limit.

### Table 2.A
Summary – Simulated impact on banks' balance sheets in 2021 of a digital euro introduction

| Deposit outflows in Q3-2021 that would have led to banks accounting for more than 10% of the banking system's total assets … | Baseline scenario | | | Robustness (50% vol. buffers) | |
|---|---|---|---|---|---|
| | Scenario A (no voluntary buffer) | Scenario B (50% vol. buffer) | Scenario C (100% vol. buffer) | Less excess reserves | Segmented interbank market |
| …experiencing unusually high quarterly (annual) wholesale funding ratio increases | 24% (100%) | 28% (100%) | 100% | 100% (100%) | 26% (100%) |
| …experiencing unusually high quarterly (annual) central bank funding ratio increases | 50% (60%) | 34% (44%) | 16% (28%) | 28% (40%) | 32% (42%) |
| …having insufficient ECB-eligible collateral | 50% | 30% | 12% | 38% | 30% |

### Table 2.B
Summary – Simulated impact on banks' balance sheets in 2021 of a bank run (not caused by a digital euro)

| Deposit outflows in Q3-2021 that would have led to banks accounting for more than 10% of the banking system's total assets having… | Crisis scenario: no interbank market, use of entire regulatory liquidity buffers |
|---|---|
| …breached their liquidity requirements | 16% |
| …needed ELA: illiquid and no eligible collateral (the first SI needing ELA) | 30% (14%) |

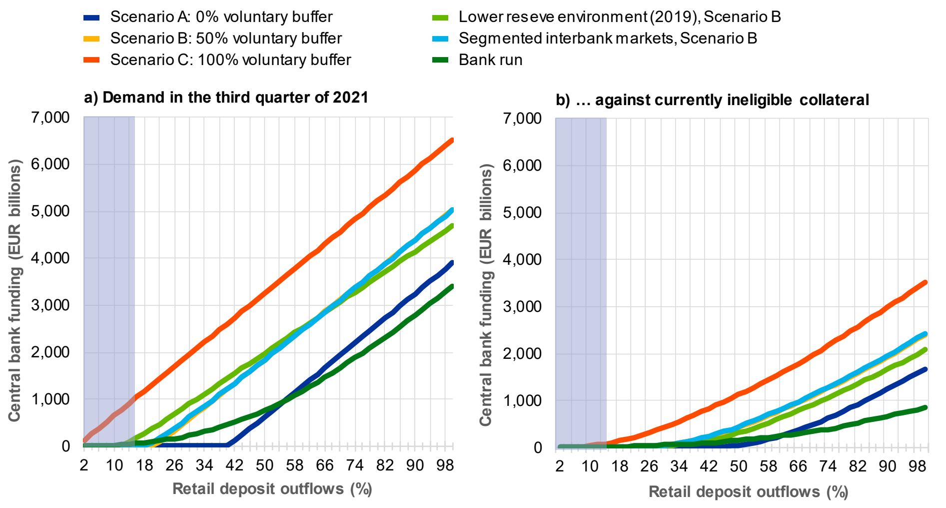
### Table 3
Percentage deposit outflows

(EUR billions)

| Outflow | 1% | 5% | 10% | 15% | 20% | 25% | 30% | 35% | 40% |
|---|---|---|---|---|---|---|---|---|---|
| Q3, 2021 | 68.6 | 343 | 686 | 1,029 | 1,371 | 1,714 | 2,057 | 2,400 | 2,742 |
| Q3, 2019 | 58.3 | 292 | 583 | 875 | 1,166 | 1,458 | 1,749 | 2,041 | 2,332 |

## Chart 14

Summary – Demand for central bank reserves for a given proportion of retail deposit outflow




Notes: The shaded area represents the possible outflows in the event of a €3,000 holding limit.

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# Appendix

## A Detailed model description

Suppose that a person wants to swap euros from a bank account into digital euros. In theory, she might be able to go to an ATM and withdraw money from her bank account in the form of banknotes and then go to the Eurosystem and deposit those banknotes there to obtain digital euros. The bank's balance sheet would decrease given that it has lost retail deposit (on the liability side) and the banknotes (on the asset side). The same happens if a bank (digitally) intermediates digital euro demand. Rather than taking out cash, that person would transfer money from her bank account to a digital euro account at the central bank. Again, the bank's banknotes or reserves at the central bank would be reduced, unless the bank obtains banknotes/reserves from the interbank market or Eurosystem. Our model formalises this intuition in what follows.

Formally, we consider a model economy with many banks. Each bank re-optimises its balance sheet after an amount $D$ of its retail deposits has been converted to digital euros. The re-optimisation is done with the aim of maximising profits, consisting of interest income $(INC)$ after deduction of interest expense (or cost of funding, $CF$).

A bank can serve its depositors' demand for CBDC by reducing its existing reserve holdings at the central bank, denoted by $R$, or by obtaining additional central bank liquidity, denoted by $CB$. Additionally, a range of interbank funding instruments are considered, including short-term secured ($STS$) funding and medium-term secured ($MTS$) funding (e.g. repo funding); short-term unsecured ($ST$) funding (e.g. interbank lending); medium-term unsecured ($MT$) funding (e.g. commercial paper); and long-term debt ($LT$) funding (e.g. bonds that are either unsecured or secured by assets not considered to be HQLAs, such as certain types of mortgages). $ST$ funding is considered to have a maturity less than one-month, $MT$ funding has a maturity between one and twelve months, and $LT$ funding has a maturity that exceeds twelve months. These differences in maturity matter for the purpose of the LCR and NSFR. Importantly, each interbank market transaction affects the balance sheet of the borrower and of the lender.

There are three types of central bank funding options included in the model. First, short-term, and long-term central bank funding obtained against HQLA collateral, $STSCB$ and $LTSCB$ respectively. These options reflect traditional central bank lending operations. Second, long-term central bank funding obtained against non-HQLA central bank eligible collateral ($LTCB$). This option reflects unconventional types of central bank lending operations. Finally, as a last resort, we allow for any residual need for liquidity to be satisfied by a special form of central bank lending which is either unsecured or secured against collateral that is currently not eligible, ($SPCB$).

Given the different funding options described above, the change in interest expense of bank i equals

$$\Delta CF_i = r^D * \Delta D_i + r^{STS} * \Delta STS_i + r^{MTS} * \Delta MTS_i + r^{ST} * \Delta ST_i + r^{MT} * \Delta MT_i + r^{LT} * \Delta LT_i + r^{STSCB} * \Delta STSCB_i + r^{LTSCB} * \Delta LTSCB_i + r^L * \Delta LTCB_i + r^{SP} * \Delta SPCB_i$$

where the interest paid on each source of funding $j$ is denoted by $r^j$. While we allow for the interest paid to differ between banks, the relative order of funding rates is assumed to be the same for all banks: $r^{STS} < r^{MTS} < r^{ST} < r^{MT} < r^{LT} < r^{STSCB} < r^{LTSCB} < r^{SPCB}$.[20]

The change in the interest income is equal to the change in the return on reserve holdings and interbank lending instruments

$$\Delta INC_i = r^R * \Delta R_i^{TOT} + r^{STS} * \Delta STSL_i + r^{MTS} * \Delta MTSL_i + r^{ST} * \Delta STL_i + r^{MT} * \Delta MTL_i + r^{LT} * \Delta LTL_i,$$

where $r^R$ is the return on central bank reserves, $\Delta R^{TOT}$ is the total change in central bank reserves, including reserves exchanged for digital euro ($\Delta R_i^{OWN}$) and those traded on the interbank market ($\Delta R_i^{IB}$), equal to the sum of the various types of interbank loans denoted by $STSL, MTSL, STL, MTL, LTL$. We assume that the rate on reserves provides a floor to market rates, or $r^R < r^{STS}$. Thus, it is profitable to lend excess reserves on the interbank market. We do not consider that in the medium-term banks might change their loan portfolio in response to a change in funding structure.

We can now specify bank $i$'s re-optimisation problem. For a given outflow of retail deposits, all banks simultaneously choose their balance sheet adjustment, including their role on the interbank market, by solving

$$\max_{R_i^{OWN},STS,MTS,ST,MT,LT,STSCB,LTSCB,LTCB,SPCB,STSL,MTSL,STL,MTL,LTL} (\Delta INC_i - \Delta CF_i),$$

subject to the following constraints

$$\Delta D_i = \Delta R_i^{OWN} - (\Delta STS_i + \Delta MTS_i + \Delta ST_i + \Delta MT_i + \Delta LT_i + \Delta STCB_i + \Delta LTCB_i + \Delta SPCB_i) \quad (1)$$

$$R + \Delta R_i^{OWN} + \Delta R_i^{IB} \geq 0 \quad (2)$$

$$\sum_i \Delta STSL_i = \sum_i \Delta STS_i \text{ (3a)}$$

$$\sum_i \Delta MTSL_i = \sum_i \Delta MTS_i \text{ (3b)}$$

$$\sum_i \Delta STL_i = \sum_i \Delta ST_i \text{ (3c)}$$

$$\sum_i \Delta MTL_i = \sum_i \Delta MT_i \text{ (3d)}$$

$$\sum_i \Delta LTL_i = \sum_i \Delta LT_i \text{ (3e)}$$

[20] As profitability does not fall within the scope of our paper, the interest rate on retail deposits relative to other funding options is irrelevant. However, the model could accommodate bank specific interest rates for the purpose of studying profitability, in which case also the interest rate on deposits relative to other funding option gains relevance.

$$\Delta STS_i + \Delta MTS_i \leq \sum_j \frac{c_{j,i}}{haircut\ c_j}, \quad where\ c_{j,i} = HQLA\ collateral\ j\ at\ bank\ i \tag{4}$$

$$\Delta STSCB_i + \Delta LTSCB_i \leq \sum_j \frac{c_{j,i}}{haircut\ c_j} - (\Delta STS_i + \Delta MTS_i), \quad where\ c_{j,i} = HQLA\ collateral\ j\ at\ bank\ i \tag{5a}$$

$$\Delta LTCB_i \leq \sum_j \frac{c_{CB\,j,i}}{haircut\ c_j} - (\Delta STS_i + \Delta MTS_i + \Delta STSCB_i + \Delta LTSCB_i), \quad where\ c_{CB\,j,i} = CB\ eligible\ collateral\ j\ at\ bank\ i \tag{5b}$$

$$LCR_i \geq 100\% + buffer_i, \tag{6}$$

$$NSFR_i \geq 100\% + buffer_i. \tag{7}$$

Constraint 1 means that each bank matches its deposit outflow with its own central bank reserves or those obtained on the interbank market.[21] Constraint 2 ensures that the bank does not draw down or lend more central bank reserves than it owns ($R$). Constraints 3a-3e capture the aggregate interbank market liquidity position. Each interbank lending transaction requires a buying bank and selling bank. Constraint 4 reflects the fact that banks have a limited stock of HQLA collateral suited to obtaining secured market lending. The following unencumbered assets are included in the available stock of HQLAs, at market value and with asset-specific haircuts: government bonds, bonds issued by supra-national institutions, third-country bonds, regional government bonds, corporate bonds, high-quality covered bonds and qualifying asset-backed securities (ABS). Constraints 5(a)-5(b) determine the type of central bank funding, given that each bank only has a limited stock of HQLA and non-HQLA central bank eligible collateral.

Constraints 6 and 7 ensure that the bank continues to meet its LCR and NSFR regulatory requirements, including any possible bank-specific voluntary liquidity buffer. These constraints are not only crucial determinants of a bank's preferred funding option in case of deposit outflows, but also of a bank's choice to act as a lender on the interbank market (as long as this does not increase their liquidity risk beyond their preferred levels) and of the choice which collateral to encumber first. The LCR and the NSFR are impacted by the following: 1) if assets are encumbered or sold, they do not qualify as unencumbered HQLAs and require more stable funding; 2) different forms of funding have different liquidity risks depending on their maturity and on whether or not they are secured; 3) the fact that interbank lending lowers reserves and may increase required stable funding and/or expected outflow.

The new LCR, after balance-sheet re-optimisation, is calculated as

$$LCR_i = \frac{\widehat{HQLA}_i + \Delta HQLA_i}{E[\widehat{outflow}]_i + \Delta E[outflow]_i}$$

where the variables with a circumflex represent the initial stock of unencumbered $HQLA$s and the initial expected outflow. Once assets are encumbered, they no

[21] Note that $\Delta D_i, \Delta R < 0$ while $\Delta STS_i, \Delta MTS_i, \Delta ST_i, \Delta MT_i, \Delta LT_i, \Delta STCB_i,\ \Delta LTCB_i, \Delta SPCB_i > 0$.

longer qualify as unencumbered HQLAs. Reserves are considered to be HQLAs, consequently using or lending reserves on the interbank market lowers the stock of unencumbered HQLAs. Thus, the change in $HQLA$s is given by

$$\Delta HQLA_i = \Delta R_i^{TOT} - HQLA\ adjustment\ due\ to\ bank\ i's\ secured\ borrowing + HQLA\ adjustment\ due\ to\ bank\ i's\ lending,$$

$$where\ HQLA\ adjustment\ due\ to\ bank\ i's\ secured\ borrowing = \Delta STS_i + \Delta MTS_i + \Delta STSCB_i + \Delta LTSCB_i$$

$$and\ HQLA\ adjustment\ due\ to\ bank\ i's\ lending = \Delta STSL_i + \Delta MTSL_i + \alpha\ \Delta LTL_i$$

The first equality uses the assumption that the haircuts imposed by the market are the same as those imposed by the ECB collateral framework, which are the same as the LCR haircut for the assets under consideration. It should be noted that each collateral asset has a different haircut. The second equality reflects that in repo transactions the HQLA value of the lending bank is unaffected while a long term secured loan to a financial institutions counts as HQLA with a haircut $\alpha$, equal to 15% in the euro area.

Additionally, the expected outflow changes given that i) it decreases by the contribution to the expected outflow of the withdrawn retail deposits, and ii) it increases by the expected outflow of the newly obtained funding instruments:

$$\Delta E[outflow]_i = \Delta D_i * runoff\ rate\ D_i + \sum_{f_i = STS,MTS,ST,MT,LT,STSCB,LTSCB,LTCB,SPCB} (\Delta f_i * runoff\ rate\ f_i)$$

Second, the new NSFR, after balance-sheet re-optimisation, is calculated as

$$NSFR_i = \frac{\widehat{ASF_i} + \Delta ASF_i}{\widehat{RSF_i} + \Delta RSF_i}$$

where the variables with a circumflex represent the initial stock of available stable funding ($ASF$) and the initial stock of required stable funding ($RSF$).

The available stable funding changes given that i) it decreases by the contribution to the initial $ASF$ of the withdrawn retail deposits, and ii) it increases by the contribution of the newly obtained funding sources, or

$$\Delta ASF_i = \Delta D_i * ASF\ factor\ D_i + \sum_{f_i = STS,MTS,ST,MT,LT,STSCB,LTSCB,LTCB,SPCB} (f_i * ASF\ factor\ f_i)$$

The $RSF$ increases given that i) encumbered assets obtain a RSF factor of 100%, while unencumbered assets have asset-specific RSF factors, and ii) loans to financial institutions may have a positive RSF factor, while reserves do not

$$\Delta RSF_i = \sum_j \Delta RSF\ factor_j\ x\ collateral\ j\ of\ bank\ i\ encumbered\ when\ borrowing + \sum_{l_i = STSL,MTSL,STL,MTL,LTL} (l_i * RSF\ factor\ l_i),$$

$$where\ \Delta RSF\ factor_j = RSF\ factor\ unencumbered\ c_{i,j} - RSF\ factor\ encumbered\ c_{i,j}$$

$$and\ the\ collateral\ of\ bank\ i\ encumbered\ when\ borrowing = \frac{1}{haircut\ c_j} x\ encumbered\ c_{i,j}$$

### Discussion of key assumptions

There are several assumptions required to operationalise our analysis. First, we assume that each bank experiences a range of outflows of retail deposits, set as a percentage of its total retail deposits. Since banks experience the same percentage of outflows, the absolute amounts differ.

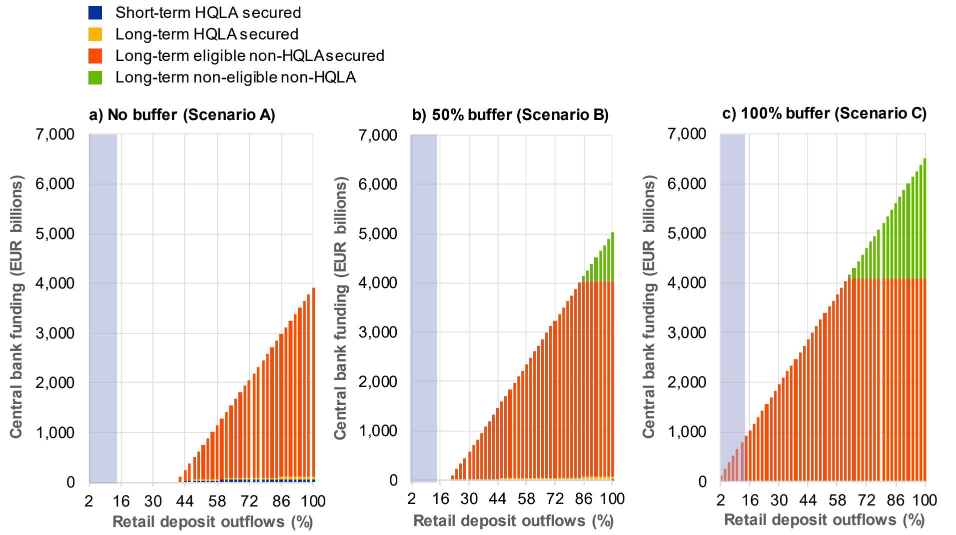
Second, we assume an order of relative prices. In normal times, short-term wholesale funding rates tend to be above the deposit facility rate (DFR) and below the main refinancing operations (MRO) rate. Bank bond issuance (or long-term non-HQLA secured market funding) is the most expensive option. It is less clear where the medium-term wholesale funding would sit. As spreads are very compressed currently, we assume that they are more expensive than short-term wholesale funding but less expensive than MROs. We assume that central bank funding could be obtained against HQLA collateral, as well as non-HQLA collateral that is included in the additional credit claim (ACC) framework, but also non-HQLA collateral that is excluded from that framework. The latter is included with the aim of modelling the potential need for unconventional monetary policy operations when the digital euro is introduced. It is only available at a penalty rate and is only used if a bank is unable to obtain liquidity otherwise.

Third, for simplicity we have not explicitly included the option for banks to sell assets to other banks or to the central bank, which could happen, for instance, when there is a quantitative easing programme. Selling an asset has almost the same impact on liquidity risk as using the asset as collateral in secured borrowing with a maturity of more than one year. The only difference between the two options is the haircut that is applied to the asset if it is not sold but encumbered, but we expect this to have a minor impact and therefore not alter our conclusions. Selling assets would, however, have an impact on bank funding structures. Furthermore, we do not take into consideration any changes in bank loan portfolios.

# B Additional results

## Chart B.1

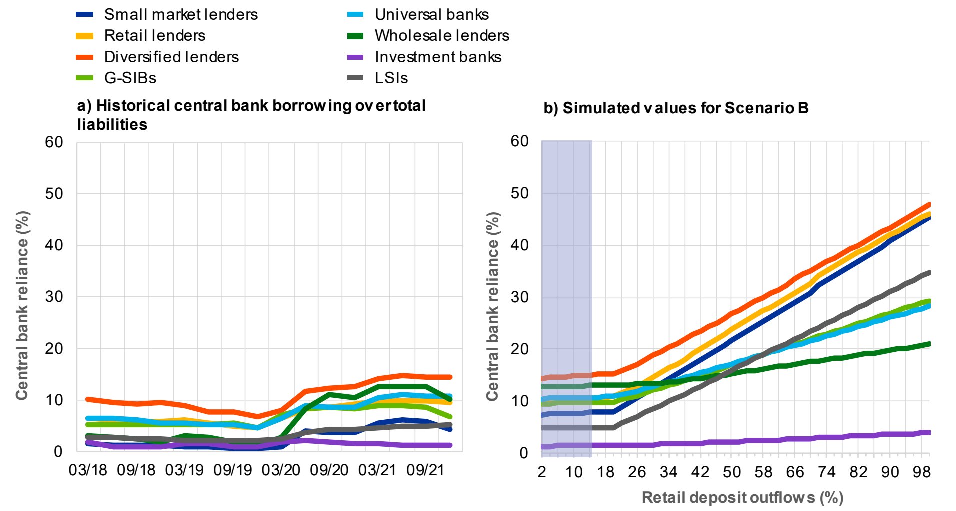
Required central bank funding by type during a digital euro introduction and with a liquid interbank market for eligible non-HQLA collateral




Notes: The shaded area represents the possible share of deposit outflows in the event of a €3,000 holding limit.

## Chart B.2

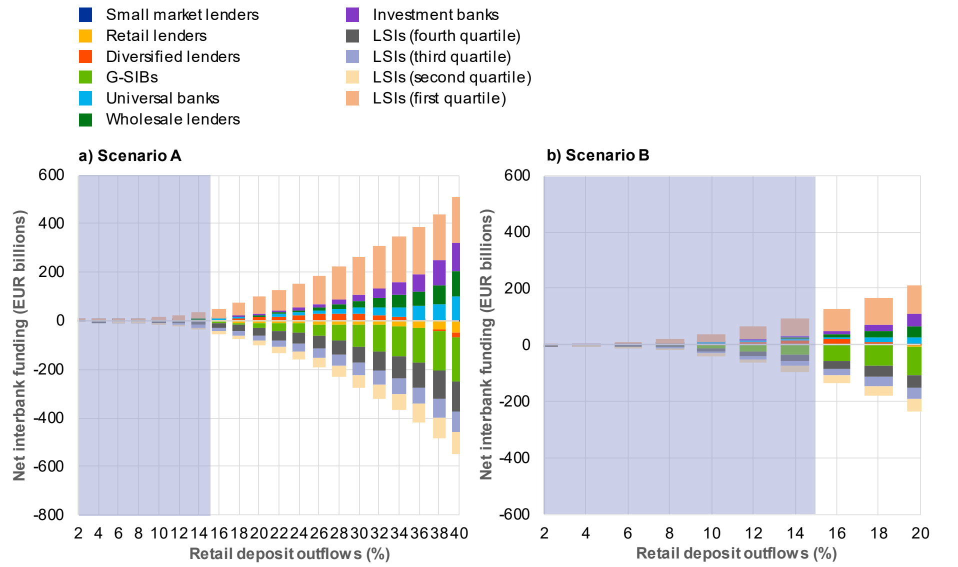
Changes in central bank reliance, aggregated over the different business models




Notes: The shaded area represents the possible outflows in the event of a €3,000 holding limit.

## Chart B.3

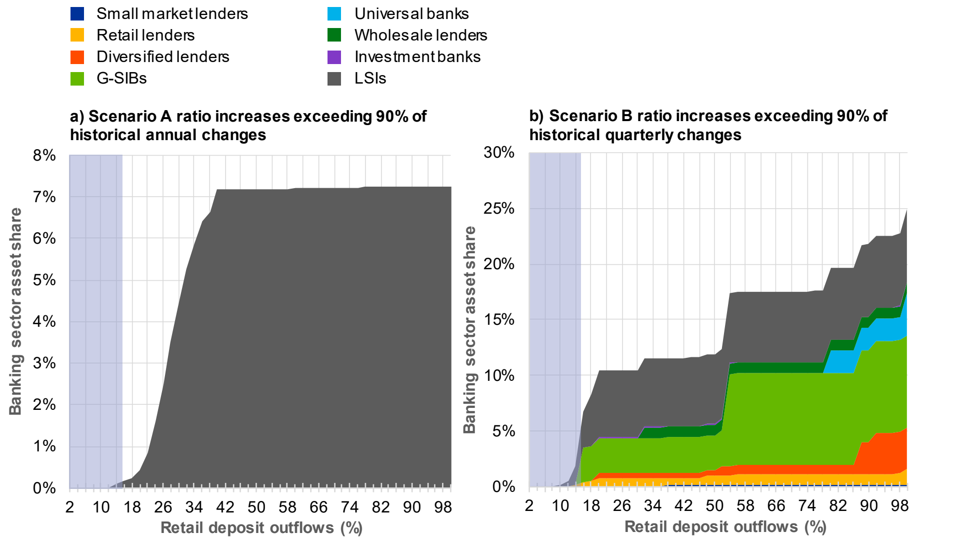
Net interbank market funding position




Notes: The shaded area represents the possible outflows in the event of a €3,000 holding limit.

## Chart B.4

Significant changes in wholesale funding ratios in less extreme cases




Notes: The historical increases are those since 2016. The shaded area represents the possible outflows in the event of a €3,000 holding limit.

**Table B.1**

Country-specific ability to accommodate deposit outflows

| Country | Relative size of country's banking sector | Share of retail deposit outflows the country's banking sector can accommodate on its own without additional reserves from the Eurosystem | | Required central bank funding secured by non-eligible collateral For: Scenario B; 50% of retail deposit outflows | |
|---|---|---|---|---|---|
| | | Scenario A | Scenario B | In € billion | As share of outflows |
| France | 29.2% | 44% | 22% | 80 | 10% |
| Germany | 24.6% | 38% | 20% | 223 | 29% |
| Spain | 12.2% | 34% | 20% | 40 | 7% |
| Italy | 10.2% | 38% | 20% | 69 | 15% |
| Netherlands | 8.7% | 44% | 22% | 13 | 4% |
| Austria | 3.4% | 40% | 22% | 23 | 17% |
| Belgium | 2.7% | 100% | 64% | 0 | 0% |
| Finland | 2.6% | 52% | 26% | 9 | 12% |
| Ireland | 2.2% | 76% | 44% | 0 | 0% |
| Luxembourg | 1.1% | 100% | 46% | 1 | 2% |
| Greece | 1% | 30% | 18% | 17 | 31% |
| Portugal | 1% | 50% | 38% | 0 | 0% |
| Slovakia | 0.3% | 24% | 14% | 6 | 48% |
| Cyprus | 0.2% | 100% | 56% | 0 | 0% |
| Estonia | 0.2% | 50% | 26% | 2 | 22% |
| Slovenia | 0.1% | 36% | 24% | 1 | 16% |
| Malta | 0.1% | 48% | 32% | 0 | 2% |
| Latvia | 0.1% | 50% | 38% | 1 | 10% |
| Lithuania | 0.1% | 68% | 34% | 0 | 3% |
| Bulgaria | 0.1% | 52% | 28% | 0 | 0% |
| Hungary | 0% | 34% | 20% | 0 | 8% |
| Euro area | 100% | 40% | 20% | 489 | 14% |

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**Barbara Meller**
European Central Bank, Frankfurt am Main, Germany; email: barbara.meller@ecb.europa.eu

**Oscar Soons**
De Nederlandsche Bank, Amsterdam, The Netherlands; email: o.c.soons@dnb.nl



Postal address 60640 Frankfurt am Main, Germany
Telephone +49 69 1344 0
Website www.ecb.europa.eu



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