2024-12-10 – ERPB - Annex to preliminary methodology for holding limit calibration

As part of the digital euro project, the ECB is working with experts from the national central banks of the Eurosystem and national competent authorities to develop a methodology for setting digital euro holding limits, balancing user experience with monetary policy and financial stability implications. This work will allow the ECB to determine the factors to be considered in the calibration, and to propose a methodology to calibrate the digital euro holding limits. It includes consultation with market participants through the European Retail Payments Board (ERPB members). This annex to ECB presentation delivered on 10 December 2024[1] provides a detailed description of the tools being developed for Blocks 1 and 3 and aims to collect feedback from ERPB members on these tools.

This working document has not been adopted or endorsed by ECB decision making bodies and therefore any views expressed shall not, under any circumstances, be regarded as an official position of the ECB. This content is intended solely to facilitate discussions and feedback by experts from the ERPB associations to be provided to the ECB digital euro project team.

Block 1: Usability - tools in detail

Consumption and income analysis

The consumption analysis encompasses an assessment of consumption patterns both at the euro area level and on a country-specific basis, capturing national heterogeneity. This analysis relies on data from the HFCS[2], which collects detailed household-level data on finances and consumption. In detail, the analysis of the consumption distribution is conducted using a two-step approach.

In the first step, key expenditure categories such as spending on consumer goods and services (e.g., utilities, food, childcare, and healthcare), travel, holidays, and regular payments (e.g., alimony and charitable donations) are considered. These expenditures are adjusted to reflect monthly individual spending. In the second step, the funds available for individual consumption are added to the consumption calculated in the first step. These funds are primarily represented by the available balance, defined as the difference between monthly income and monthly consumption computed in step one. Rent and mortgage payments are excluded from the available balance. This step helps account for additional potential use cases for digital euro spending that would not be captured otherwise. For instance, additional potential use cases for digital euro spending could include subscriptions to private services, such as streaming platforms, as well as expenditures on leisure activities beyond holidays and travel, like entertainment, recreational sports, or cultural events. The inclusion of such category is ultimately leading to a more comprehensive estimate of potential monthly liquidity needs for consumption. Currently, the analysis excludes rent, loan repayments, and mortgage payments due to

[1] See ECB, Update on work on methodology for holding limit calibration – agenda item 3.
[2] See ECB, Household Finance and Consumption Survey (HFCS).

data quality and data limitations. If included, these expenses would be expected to significantly increase the calculated individual monthly consumption.

A complementary dimension of the analysis, which has also been examined in other jurisdictions[3] and introduced based on the feedback by ERPB members, relates to the feasibility of individuals to receive their income directly into their digital euro account. Understanding whether holding limits could potentially interfere with individuals' ability to seamlessly receive, store, and use their income is another element for further refining a holding limit that aligns with users' needs. The analysis of the income distribution incorporates all key variables related to various income sources collected from the HFCS. In calculating the individual monthly income, the analysis takes into account economically active household members, including pensioners receiving any form of income. This monthly income is then converted into net income by applying the appropriate income tax rates and social security contributions, using data from both the HFCS dataset and the OECD. The resulting net monthly income is further supplemented by the balance carried over from the previous month, which is defined as the difference between monthly income and monthly consumption, as calculated earlier in step one. Importantly, the balance from the previous month excludes rent and mortgage payments due to data quality and data limitations.

Ad-hoc survey on users' behaviour and their money demand

The analysis is augmented by conducting a new dedicated survey on user behaviour regarding holding digital euro, performed by an external service provider. This approach aims to tackle structural difficulties in comprehending user behaviour, which is critical but challenging to predict due to the inability to directly compare with traditional payment methods (such as physical cash or cashless payments using commercial bank money) and the fact that user behaviour is not only heterogeneous but also evolves over time. While exercises like this survey have structural limitations due to the inherent difficulty in capturing preferences over hypothetical questions about something not yet fully known to users (such as the digital euro), the findings could be used to refine the methodology. For instance, its results can be used to cross-check the monthly expenses figures and provide further data points that can help model the scenarios.

Methodologically, the survey is representative of the euro area population and has been tested in a pilot to ensure participants fully understand the questions. The survey is designed to be concise (20-minutes duration) and incudes the provisions of stimuli. Respondents are provided with basic information about the digital euro to ensure they are well-equipped to answer all questions. This information is shared gradually, allowing for easier comprehension. Sufficient context and stimulus material is offered to help participants provide informed responses. This includes context on the rationale behind the holding limit. Finally, the service provider employs scenario-based descriptions to transit from abstract theoretical questions about unfamiliar experiences to more relatable experiences.

The overall survey is composed of 21 relatively simple questions and recruits a representative sample of participants aged 18 and above, targeting 1,000 individuals per euro area country, with three countries (Malta, Luxembourg, and Cyprus) involving 500 respondents.

[3] See Bank of England and HM Treasury (2023), pp. 80-81.

Block 3: Financial stability and banking supervision - tools in detail

The balance sheet optimization model closely follows Meller and Soons (2023), which was previously published as an ECB Occasional Paper. This more detailed model description can be found in Meller and Soons (2024).

Model environment

The model considers a one-period model economy with many profit-maximising banks, each differing in their balance sheets: their level of reserve holdings, deposits, collateral, and liquidity risk profiles. Each bank i re-optimises its balance sheet under the expectation that an amount ΔD_i of its retail deposits will be converted to digital euros. Banks can respond to digital euro demand in three general ways, each with a different impact on their constraints: 1) by drawing down their current central bank reserves or banknotes, 2) by increasing central bank borrowing, and 3) by obtaining additional central bank reserves on the interbank market.[4]

On the interbank market, each bank *i* can choose from a variety of funding options offered by bank j, either unsecured or secured against unencumbered High-Quality Liquid Asset (HQLA) k: short-term secured (STS_{ijk}) funding, medium-term secured (MTS_{ijk} and $MTLS_{ijk}$) funding (e.g. repos) and long-term secured (LTS_{ijk}) funding (e.g. covered bonds); short-term unsecured (ST_{ij}) funding (e.g. money market funding); medium-term unsecured (MT_{ij} and $MLTS_{ij}$) funding (e.g. commercial paper); and long-term unsecured (LT_{ij}) funding. For the purposes of our model, short-term funding is considered to have a maturity less than one-month, medium term funding has a maturity between one and six months (MT) or between six and twelve months (MLT), and LT_{ij} funding has a maturity that exceeds twelve months. Moreover, secured funding is defined to be secured by a HQLA, k, while unsecured funding is not. These differences in maturity and collateral are chosen because of the different impacts they have on a bank's regulatory liquidity ratios.

There are six types of central bank funding options included in the model, where it is assumed that the central bank provides as much liquidity as banks demand. First, bank i can obtain short-term secured ($STSCB_{ik}$) and long-term secured ($LTSCB_{ik}$) central bank funding against HQLA collateral k. Second, bank i can also obtain central bank funding against non-HQLA central bank eligible collateral l, at both maturities ($STCB_{il}$ and $LTCB_{il}$). Finally, as a last resort, the model allows for any residual need for liquidity to be satisfied by a special form of central bank lending which is secured against collateral that is currently not eligible. This funding option is also available at both maturities ($SPSTCB_i$, $SPLTCB_i$). These final funding options are included with the aim of modelling the possible "residual" need for unconventional monetary policy operations when a 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.

[4] As explained in Adalid et al. (2022), there is a fourth option which we do not consider as the added value is limited: the bank could sell assets. A bank can only obtain additional reserves if it sells asset to another bank or a client of another bank. The subsequent redistribution of reserves and impacts on the various constraints (collateral, LCR, NSFR) are very similar to those resulting from secured interbank market funding. Therefore, explicitly incorporating this adjustment option does not yield additional insights.

The impact of digital euro demand on banks' cost of funding and net interest income

What happens to bank *i*'s funding costs? The introduction of a digital euro is assumed to lead to a decrease in bank *i*'s retail deposits, ΔD_i. Consequently, bank *i* might need to raise reserves by increasing its interbank or central bank funding. This leads to a change in bank *i*'s cost of funding, ΔCF_i:

$$\Delta CF_i = r_i^D * \Delta D_i + r_i^{STS} * \sum_j \sum_k \Delta STS_{ijk} + r_i^{MTS} * \sum_j \sum_k \Delta MTS_{ijk} + r_i^{MLTS} * \sum_j \sum_k \Delta MLTS_{ijk} + r_i^{LTS} * \sum_j \sum_k \Delta LTS_{ijk} + r_i^{ST} * \sum_j \Delta ST_{ij} + r_i^{MT} * \sum_j \Delta MT_{ij} + r_i^{MLT} * \sum_j \Delta MLT_{ij} + r_i^{LT} * \sum_j \Delta LT_{ij} + r_i^{STSCB} * \sum_k \Delta STSCB_{ik} + r_i^{LTSCB} * \sum_k \Delta LTSCB_{ik} + r_i^{STCB} * \sum_l \Delta STCB_{il} + r_i^{LTCB} * \sum_l \Delta LTCB_{il} + r_i^{SPSTCB} * \Delta SPSTCB_i + r_i^{SPLTCB} * \Delta SPLTCB_i,$$

where r_i^D denotes the retail deposit rate paid by bank *i*. The rate r_i^s is paid by the borrowing bank *i* and received by the lending bank *j* for an interbank funding instrument $s \in \{STS_{ijk},\ MTS_{ijk},\ MLTS_{ijk},\ LTS_{ijk},\ ST_{ij},\ MT_{ijk},\ MLT_{ijk},\ LT_{ij}\}$.

What happens to bank *i*'s income? As a result of digital euro-induced deposit outflows, bank *i* might need to draw down its own reserves to intermediate digital euro demand of its own depositors and/or might be in the position to lend to other banks on the interbank market (if it still has sufficient reserves and a liquidity buffer). The resulting change in bank *i*'s net interest income, ΔINC_i, equals:

$$\Delta INC_i = r^R * \Delta R_i + \sum_j r_j^{STS} * \sum_k \Delta STS_{jik} + \sum_j r_j^{MTS} * \sum_k \Delta MTS_{jik} + \sum_j r_j^{MLTS} * \sum_k \Delta MLTS_{jik} + \sum_j r_j^{LTS} * \sum_k \Delta LTS_{jik} + \sum_j r_j^{ST} * \Delta ST_{ji} + \sum_j r_j^{MT} * \Delta MT_{ji} + \sum_j r_j^{MLT} * \Delta MLT_{ji} + \sum_j r_j^{LT} * \Delta LT_{ji},$$

where r^R is the rate paid by the central bank on excess reserves held as central bank deposits. The change in central bank reserves is denoted by ΔR_i and is made up of the change in own reserves due to bank *i*'s own digital euro intermediation and the change in own reserves lent out on the interbank market.

The bank optimisation problem

This section specifies bank *i*'s optimisation problem. For a given outflow of retail deposits, a bank chooses its balance sheet adjustment with the aim of maximizing profits by solving:

$$\max_{\Delta R_i, \Delta STS_{ijk}, \Delta MTS_{ijk}, \Delta MLTS_{ijk}, \Delta LTS_{ijk}, \Delta ST_{ij}, \Delta MT_{ij}, \Delta MLT_{ij}, \Delta LT_{ij}, \Delta STSCB_{ik}, \Delta LTSCB_{ik}, \Delta STCB_{il}, \Delta LTCB_{il}, \Delta SPSTCB_i, \Delta SPLTCB_i, \Delta STS_{jik}, \Delta MTS_{jik}, \Delta LTS_{jik}, \Delta ST_{ji}, \Delta MT_{ji}, \Delta LT_{ji}} (\Delta INC_i - \Delta CF_i)$$

subject to bank *i*'s constraints (1)-(6) and interbank market clearing conditions (7)-(11).

$$\Delta D_i = \Delta R_i - \sum_j \left(\sum_k \left(\Delta STS_{ijk} + \Delta MTS_{ijk} + \Delta MLTS_{ijk} + \Delta LTS_{ijk} \right) + \Delta ST_{ij} + \Delta MT_{ij} + \Delta MLT_{ij} + \Delta LT_{ij} \right) - \sum_k (\Delta STSCB_{ik} + \Delta LTSCB_{ik}) - \sum_l (\Delta STCB_{il} + \Delta LTCB_{il}) - \Delta SPSTCB_i - \Delta SPLTCB_i \quad (1)$$

$$R_i - MRR * \Delta D_i + \Delta R_i - \sum_j \left(\sum_k (\Delta STS_{jik} + \Delta MTS_{jik} + \Delta MLTS_{jik} + \Delta LTS_{jik}) + \Delta ST_{ji} + \Delta MT_{ji} + \Delta MLT_{ji} + \Delta LT_{ji} \right) \geq 0 \quad (2)$$

$$\sum_j (\Delta STS_{ijk} + \Delta MTS_{ijk} + \Delta MLTS_{ijk} + + \Delta LTS_{jik}) + \Delta STSCB_{ik} + \Delta LTSCB_{ik} \leq (1 - haircut\ c_k) * c_{i,k}\ \forall\ k \quad (3)$$

$$\Delta STCB_{il} + \Delta LTCB_{il} \leq (1 - haircut\ cbc_l) * cbc_{i,l}\ \forall\ l \quad (4)$$

$$LCR_i \geq 100\% + LCR\ buffer_i \quad (5)$$

$$NSFR_i \geq 100\% + NSFR\ buffer_i \quad (6)$$

Constraint (1) means that each bank must account for all its deposit outflow either by depleting its own central bank excess reserves (ΔR_i) or those newly obtained on the interbank market or from the central bank. Constraint (2) ensures that the bank does not draw down or lend more excess central bank

reserves than it currently owns. The term "$MRR * \Delta D_i$" reflects that bank's excess reserves increase as those reserves held for the purpose of the minimum reserve requirement (MRR) for those deposits which are withdrawn are then considered excess reserves. Since constraint (2) must hold for all banks, it also ensures that no more reserves are used by the banking sector than available on aggregate. If a bank uses reserves to meet its costumers' demand for digital euro, 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 excess reserves in the system.

Constraints (3) – (4) represent the collateral constraints (see also below). It is denoted with c_{ik} the market value of unencumbered HQLA collateral k of bank i that can be pledged on the interbank market or at the central bank and cbc_{il} denotes the market value of unencumbered non-HQLA central bank eligible collateral l of bank i (which is not accepted on the interbank market). Constraint (3) reflects that banks have a limited stock of each category of HQLA collateral suited to obtaining secured market and central bank funding. Collateral in secured lending is subject to a haircut. To easy notation, It is assumed in the model presentation that haircuts are the same on the interbank market and at the central bank. However, when the model is run, these haircuts will in fact differ. The haircuts are defined such that a haircut of 0.05 (5%) means that €100 of collateral would provide €95 in secured funding. Constraint (4) reflects that each bank only has a limited stock of each category of non-HQLA central bank eligible collateral. HQLA from non-HQLA collateralised central bank funding it are separated as it allows to judge how important it is for the central bank to offer a broad collateral framework in case of a digital euro introduction.

Regulatory liquidity ratios

Banks must meet two regulatory liquidity requirements: the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR). The LCR mandates that the market value of a bank's HQLA, which can be monetised on short notice, exceeds its expected net outflows within a 30-day stress period. Expected outflows are calculated by multiplying the liabilities of a bank with a liability specific "run off rate". HQLA holdings are based on the market value of HQLAs adjusted by an "LCR factor" which can be interpreted as a regulatory haircut on assets to account for market/liquidation risks. The NSFR ensures that the bank maintains sufficient Available Stable Funding (ASF) compared to its Required Stable Funding (RSF). The NSFR is calculated based on "factors reflecting supervisory assumptions assigned to the bank's sources of funding and to its exposures, with these factors reflecting the liquidity characteristics of each category of instruments" (BIS, 2014). In practice, a bank's ASF is calculated as the sum of the bank's liabilities multiplied by a regulatory "ASF factor", where unsecured, short-term funding obtains a 0% factor and funding above one year a factor of 100%. A bank's RSF is the sum of the market value of a bank's (encumbered) asset holdings multiplied by an "RSF factor", which is 0% for reserves, the most liquid asset, and 100% for all assets that are encumbered for a period of one year or more.

Constraints (6) and (7) of the bank's optimisation problem ensure that each bank continues to meet its LCR and NSFR requirements and possibly sustain a bank-specific voluntary liquidity. The regulatory requirements constrain both, the bank's set of feasible borrowing and the set of feasible lending options. Regarding the latter, a bank is not able to act as a lender on the interbank market if this would increase its liquidity risk beyond its preferred level.

An important input in our model is the extent to which banks are willing and allowed and willing to deplete their liquidity buffers. In Q1 2024, the observed LCR and NSFR values in our sample range from just above the regulatory minimum (100%) to more than ten times the regulatory minimum. The observed variation of liquidity buffers likely reflects persistent heterogeneous liquidity risk preferences. It is likely that banks with high voluntary liquidity buffers would prefer to maintain relatively high buffers following a digital euro introduction.

Rather than assuming that all banks would be willing to reduce their liquidity buffer by the same absolute amount, we assume that in the business-as-usual scenario SIs are only willing to deplete their liquidity buffers to their internal liquidity targets, as reported in the SSM data collection. Since for LSIs we lack the data, we assume that they are willing to deplete the same share of their current liquidity buffers as the SIs with the business model of small market lenders. In the flight-to-safety scenario, we assume that banks are willing to deplete their liquidity buffers until the regulatory minimum.

Liquidity Coverage Ratio

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

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

where the variables with a circumflex represent the initial stock of unencumbered HQLAs and the initial expected net outflows within a 30-day stress period.

The LCR numerator, i.e., the unencumbered HQLA stock, is impacted by the digital euro-induced changes to the bank's balance sheet in two ways. First by a decrease in reserves: the unencumbered HQLA stock is reduced either by drawing down own reserves to deal with own deposit outflows or by lending out reserves on the interbank market. Second by secured borrowing or lending: the unencumbered HQLA stock decreases when the bank borrows against HQLAs and unencumbered HQLAs received in secured transactions may be considered as part of the stock of HQLA. Note that, although similar in spirit, there can be a difference between "$haircut\ c_k$" of a HQLA and its "$LCR\ factor_k$". Thus, the change in the market value of unencumbered HQLA is given by:

$$\begin{aligned}\Delta HQLA_i = {} & \Delta R_i^{TOT} - \sum_j \sum_k \frac{(1 - LCR\ factor_k)}{(1 - haircut\ c_k)} * (\Delta STS_{ijk} + \Delta MTS_{ijk} + \Delta MLTS_{ijk} + \Delta LTS_{ijk} + \Delta STSCB_{ik} + \Delta LTSCB_{ik}) \\ & + \sum_j \sum_k \frac{(1 - LCR\ factor_k)}{(1 - haircut\ c_k)} * \left(\Delta STS_{jik} + \Delta MTS_{jik} + \Delta MLTS_{ijk} + \Delta LTS_{jik}\right) + \psi_{LTL} * \Delta LTL_{ji},\end{aligned}$$

where the market value of collateral is adjusted using the collateral specific haircut and LCR factor. It also includes the fact that the market value of collateral received in repo transactions may count toward a bank's stock of HQLAs. ψ_{LTL} captures that a long-term security not issued by the bank itself may partially count as HQLA.

Also, the LCR numerator, the expected net outflows during a 30-day stress period, is impacted by the digital euro-induced balance sheet changes. Once deposits are withdrawn, expected outflows decreases by the withdrawn deposits multiplied by their respective run-off rate. The run-off rate differentiates between stable and less stable deposits. However, net expected outflows may also increase depending on the run-off rate of the newly obtained interbank funding instruments and the

expected inflow resulting from loans to other financial institutions. Thus, the total change in the expected outflow of bank i is given by:

$$\begin{aligned}\Delta E[net\ outflow]_i &= \Delta D_i * run\ off\ rate\ D_i \\ &+ \sum_{f=STS,MTS,MLTS,LTS,STSCB,LTSCB} \sum_j \sum_k (\Delta f_{ijk} * run\ off\ rate\ f_{ijk} - \Delta f_{jik} \\ &* inflow\ rate\ f_{jik}) \\ &+ \sum_{f=STCB,LTCB} \sum_j \sum_l (\Delta f_{ijl} * run\ off\ rate\ f_{ijl} - \Delta f_{jil} * inflow\ rate\ f_{jil}) \\ &+ \sum_{f=ST,MT,MLT,LT,SPSTCB,SPLTCB} \sum_j (\Delta f_{ij} * run\ off\ rate\ f_{ij} - \Delta f_{ji} * inflow\ rate\ f_{ji})\end{aligned}$$

Furthermore, when calculating the change in the net expected outflow, the regulatory cap on inflows is included. Expected liquidity inflows can only be recognised up to a limit of 75% of expected liquidity outflows. This additional restriction is not contained in the expression.

Net Stable Funding Ratio

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 NSFR numerator, a banks' available stable funding, may be affected in two ways. First, when deposits are withdrawn, available stable funding decreases since retail deposits are considered a stable source of funding. The extent of the decrease depends on the ASF factor assigned to the withdrawn deposits by the regulator, which differentiates between stable and less stable deposits. Second, newly obtained funding sources may be counted as available stable funding. Thus, the change in bank i's available stable funding is given by:

$$\begin{aligned}\Delta ASF_i &= \Delta D_i * ASF\ factor\ D_i + \sum_{f=STS,MTS,MTLS,LTS,STSCB,LTSCB} \sum_j \sum_k \Delta f_{ijk} * ASF\ factor\ f_{ij} \\ &+ \sum_{f=STCB,LTCB} \sum_j \sum_l \Delta f_{ijl} * ASF\ factor\ f_{ij} + \sum_{f=ST,MT,MLT,LT,SPSTCB,SPLTCB} \sum_j \Delta f_{ij} * ASF\ factor\ f_{ij}\end{aligned}$$

The NSFR denominator, representing the required stable funding, can also be affected in three ways. First, a bank's required stable funding increases when assets are encumbered, leading to a higher RSF factor being applied to these newly encumbered assets. When assets are encumbered for a period of six months to a year, they obtain a 50% RSF factor, while when they are encumbered for a period of one year or more their new RSF factor is 100%. Second, the required stable funding increases for a bank which lends on the interbank market since loans to financial institutions increase the required stable funding. Third, the newly obtained collateral in repo transactions receives a RSF factor, which depends on the type of collateral. Thus, the change ΔRSF_i is given by:

$$\Delta RSF_i = \sum_j \sum_k \frac{(0.5 - RSF\ factor_k)}{(1 - haircut\ c_k)} * (\Delta MLTS_{ijk}) + \sum_j \sum_k \frac{(1 - RSF\ factor_k)}{(1 - haircut\ c_k)} * (\Delta LTS_{ijk} + \Delta LTSCB_{ik}) + \sum_{f=STS,MTS,MLTS} \sum_j \sum_k \Delta f_{jik} * RSF\ factor\ f_{ji} + \sum_{f=ST,MT,MLT,LT} \sum_j \Delta f_{ji} * RSF\ factor\ f_{ji} + \sum_j \sum_k \frac{(1 - RSF\ factor_k)}{(1 - haircut\ c_k)} * (\Delta STS_{jik} + \Delta MTS_{jik} + \Delta MLTS_{jik})$$

The interbank market

In our baseline model specification, the interbank market is perfectly competitive and frictionless. The demand for each type of interbank loan is satisfied by a lender, but only if there is an unconstrained bank with sufficient excess reserves available to be lent out. Recall that, when a bank borrows reserves on the interbank market, the liquidity ratios of both the borrowing and lending bank are affected.

Constraints (7)-(14) represent the market clearing conditions for each type of funding. These conditions imply that, in addition to its own reserves, collateral and liquidity constraints, each bank's interbank borrowing or lending choices must also be consistent with aggregate market clearing conditions.

$$\sum_i \sum_j \Delta STS_{ij} = \sum_j \sum_i \Delta STS_{ji} \quad (7)$$

$$\sum_i \sum_j \Delta MTS_{ij} = \sum_j \sum_i \Delta MTS_{ji} \quad (8)$$

$$\sum_i \sum_j \Delta MLTS_{ij} = \sum_j \sum_i \Delta MLTS_{ji} \quad (9)$$

$$\sum_i \sum_j \Delta LTS_{ij} = \sum_j \sum_i \Delta LTS_{ji} \quad (10)$$

$$\sum_i \sum_j \Delta ST_{ij} = \sum_j \sum_i \Delta ST_{ji} \quad (11)$$

$$\sum_i \sum_j \Delta MT_{ij} = \sum_j \sum_i \Delta MT_{ji} \quad (12)$$

$$\sum_i \sum_j \Delta MLT_{ij} = \sum_j \sum_i \Delta MLT_{ji} \quad (13)$$

$$\sum_i \sum_j \Delta LT_{ij} = \sum_j \sum_i \Delta LT_{ji} \quad (14)$$

The model does not explicitly consider that banks can obtain liquidity from other private entities such as non-banks. The reason is that the impact on the distribution of reserves across banks is the same whether reserves are exchanged directly between banks or indirectly at the request of a (non-bank) customer of a bank. If a bank borrows from a non-bank, reserves are transferred from the bank where the non-bank holds its deposit (Bank B) to the borrowing bank (Bank A). This lowers the reserves at Bank B and increases the reserves at Bank A, just as it would if Bank A had borrowed directly from Bank B. The impact on its LCR for Bank A is also the same. For Bank B, the LCR impact is very similar if the alternative interbank funding would have been unsecured with a maturity of less than 30 days.

Solution algorithm

This section briefly explains the solution algorithm. First, each bank's profit-maximizing balance sheet adjustment is maximised subject to its reserve, liquidity, and collateral constraints. This balance sheet

adjustment consists of (a mix of) reserve depletion and/or secured and unsecured funding options, with different maturities and with specific collateral assets becoming encumbered. In the next step, market clearing conditions are accounted for. On the interbank market, all banks that want to borrow receive reserves accordingly if there is sufficient liquidity in the interbank market. The funding comes from and is split evenly across all banks which are willing to lend. Banks are willing to lend if they have sufficient reserves and if lending will not decrease their liquidity ratios below their preferred levels. The balance sheets and liquidity ratios of both the borrower and the lender are adjusted to account for the transaction. If no bank is willing to satisfy the demand for a specific funding option, the initial optimisation that determines the profit maximizing balance sheet adjustment is re-run with this funding option excluded. This process continues until all the interbank market clears or until no more bank is willing to lend on the interbank market. At this point, banks can only manage additional outflows by depleting their own reserves or by obtaining central bank funding.

Banks' reaction: Impact on profitability

The analysis is further complemented by an assessment of the effect on Net Interest Income (NII), which has been introduced also in view of the feedback received in the context of the ERPB discussion. NII captures the possible changes in interest income and expense due to changes in banks' balance sheets in response to deposit outflows

The impact of the digital euro introduction on banks' net interest income is assessed by considering the changes in interest income and interest expense for each balance sheet item due to the deposit outflows. More specifically, changes in interest income and expenses are determined by considering changes in the volumes of the various banks' balance sheet items. As detailed above, banks respond to deposit outflows adjusting the composition of their balance sheets. More specifically, in this framework banks can change interbank assets and liabilities, central bank funding and reserves. These changes are an outcome of the balance sheet optimization model and are multiplied by the corresponding interest rates. Interest rates for each balance sheet item are calibrated at the bank level and are assumed to remain constant. In the main analysis, we use interest rates from Q1 2024, while sensitivity analyses are conducted for different periods to assess how varying interest rate environments affect the results. Formally, the change in NII for bank *i* is expressed as:

$$\Delta \mathrm{NII}_i = \Delta INC_i - \Delta CF_i = \sum_{a \in asset} r_{i,a}\, \Delta q_{i,a} - \sum_{l \in liabilities} r_{i,l}\, \Delta q_{i,l} \ ,$$

where r represents the interest rates and q the quantities.

Collateral availability

The model is also used to cross-check the collateral availability for each bank according to the following analysis

$$\sum_i (1 - h_i) \times ac_{i,j} \geq d€R_{j,IB} + d€R_{j,CB}$$

where $\sum_{i=1}^{C}(1 - h_i) \times c_i$ represents bank j's total available unencumbered, eligible collateral, ac, after asset class specific haircuts in line with the ECB collateral framework, h_i. And $d€R_j$ is the amount of

secured funding which bank j demands in response to a digital euro, either from the interbank (IB) market or the central bank (CB), which is simulated following the methodology described above. On aggregate, banks also need to have a collateral buffer for unexpected funding needs.

The analysis is further enhanced by examining potential conditions for collateral scarcity according to the following formula:

$$\tilde{F}_s > F_{D€} + F_{MPI}$$

where F is the Eurosystem footprint in government bonds markets, defined as sum of government bonds pledged or held at the central bank for credit operations and portfolio holdings. $\tilde{F}_s$ represents the observed, asset-growth adjusted Eurosystem footprint during a period of collateral scarcity, $F_{D€}$ is the Eurosystem footprint related to the digital euro and F_{MPI} the Eurosystem market footprint due to monetary policy considerations independent of the digital euro.

Data and sample

The analysis relies on data collected via FINREP and COREP templates, which are part of the European Banking Authority's supervisory reporting requirements. These datasets provide comprehensive financial and prudential information on banks. The baseline scenario is based on a sample of 2009 euro area banks from the first quarter of 2024. The sample includes all supervised institutions in the euro area. The data includes detailed information on the asset and liability composition of each bank. The analysis uses information on banks' deposits holdings, reserve and banknotes holdings, regulatory liquidity ratios, market value of different types of HQLA and central bank eligible collateral.

This information set has been complemented by an ad-hoc data collection exercise that the SSM has carried out in July 2024 with 98 Significant Institutions (those with retail deposits). This dataset - with reference date 31 March 2024 - included granular data on information of the distribution of retail deposits held by natural persons eligible to hold digital euros, on a consolidated level. In line with the feedback received from market participants regarding the factors to be considered, this data collection has incorporated data on banks' internal liquidity targets. The data collection adheres to the regulatory reporting framework as much as possible and uses COREP ALM to complement this information and perform the necessary robustness checks.

Overall, the SSM data collection included two pillars of information: i) liquidity targets and ii) distribution of retail deposits (sight, term, and savings) disaggregated in 12 buckets or thresholds for volume of deposits, number of depositors and deposit accounts, respectively. The data also includes for each range and institution the average deposit rates paid by banks to depositors. Finally, the data includes a breakdown to determine the volume of deposits covered by deposit guarantee schemes or deemed as "stable" for supervisory purposes. This is done to gauge the level of "stickiness" of retail deposits across the entire sample.

As of beginning of December 2024, the Less Significant Institutions (LSIs) data collection had been triggered for 185 banks in all Eurosystem countries – aiming to finalize robustness checks by end of the year. The same data template has been used as for Significant Institutions to foster harmonized results across both exercises (Significant Institutions and Less Significant Institutions).

References

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