EUROPEAN CENTRAL BANK

EUROSYSTEM

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

Barbara Meller (ECB) and Oscar Soons (ECB)

28/08/2024

Presentation at the EEA annual conference Rotterdam

Views are ours and not necessarily those of the Eurosystem

Outline

1. Motivation

- Central banks are investigating the benefits and risks of introducing **retail CBDC**

- Retail CBDC is safe digital money issued by the central bank, accessible to individuals
- People may lower their cash holdings or **substitute bank deposits for CBDC**

- **Concern**: deposit outflows could increase bank liquidity risks and endanger financial stability
- **Solution**: avoid excessive outflows with dissuasive remuneration or a **limit on CBDC holdings**

1. Contribution

- How to calibrate CBDC holding limits? How would CBDC affect banks?
- **Two contributions:**

1. **Develop a broadly applicable methodology** to quantify impact of CBDC policy choices on banks
    - Simulation model with a (realistic) focus on liquidity regulation and collateral requirements and availability
    - Includes detailed modelling of bank-level constraints and the central bank balance sheet
    - Allows to consider a wide range of scenarios of interest
2. **Apply our methodology to the euro area** to inform the digital euro design
    - Using bank-level regulatory data for all supervised banks in the euro area
    - Assess the level of outflows above which banks' liquidity risk and funding structures becomes concerning

1. Contribution

- How to calibrate CBDC holding limits? How would CBDC affect banks?

- **Two contributions:**

1. **Develop a broadly applicable methodology** to quantify impact of CBDC policy choices on banks
    - Simulation model with a (realistic) focus on liquidity regulation and collateral requirements and availability
    - Includes detailed modelling of bank-level constraints and the central bank balance sheet
    - Allows to consider a wide range of scenarios of interest
2. **Apply our methodology to the euro area** to inform the digital euro design
    - Using bank-level regulatory data for all supervised banks in the euro area
    - Assess the level of outflows above which banks' liquidity risk and funding structures becomes concerning

1. Related literature

- **CBDC impact assessments:** Castrén et al.(2022), BIS (2021), Gorelova et al. (2022), Whited et al. (2023), European Commission (2023), Banca de Italia (2023), Bidder et al. (2024)
  - ➢ We complement by simultaneously accounting for the many bank-level adjustment options
  - ➢ We show the importance of considering the limited and heterogenous reserve holdings, collateral availability, and of the assumed/required role of the central bank
- **Central bank collateral policy matters for the impact of CBDC:** Williamson (2022), Burlon et al., (2023), Assenmacher et al. (2021), and Munoz and Soons (2023)
  - ➢ We complement with our empirical bank-level approach
- **CBDC demand as a determinant of the demand for central bank reserves:** Afonso et al. (2022), Lopez-Salido and Vissing-Jorgensen (2023), Abad et al. (2023)
  - ➢ We quantify the additional demand for central bank reserves due to CBDC in various scenarios

Outline

2. Bank liquidity management today

- Consider a profit-maximizing bank partly funded by retail deposits
- In case of a liquidity shock, each bank's "funding experts" decide how to adjust the banks' funding structure and manage its liquidity, subject to four main constraints:

1. Stock of cash and excess reserves
2. Stock of unencumbered (eligible) collateral
3. Liquidity coverage ratio (LCR): HQLA > net E[outflow]
4. Net Stable Funding ratio (NSFR): ASF > RSF

2. Model with CBDC in one slide

- **Constrained balance sheet optimization** model to simulate a bank's reaction to CBDC
- Assume household withdraw retail deposits for CBDC. To obtain CBDC, a bank could:

1. **draw down its own reserves**, if reserves are not depleted and bank is not LCR/NSFR constrained
2. obtain (un)secured market funding if not collateral or LCR/NSFR constrained and there is excess liquidity in the system
3. **obtain additional reserves** via central bank funding

(1–2: **"reserve redistribution"**)

Model output implies a change in **liquidity risks and central bank reliance**

2. Model in more detail: bank's objective

- **Profit-maximizing banks:**

$$\max_{\Delta R_i, \Delta STS_{ijk}, \Delta MTS_{ijk}, \Delta ST_{ij}, \Delta MT_{ij}, \Delta LT_{ij}, \Delta STSCB_{ik}, \Delta LTSCB_{ik}, \Delta LTCB_{il}, \Delta SPCB_i, \Delta STS_{jik}, \Delta MTS_{jik}, \Delta ST_{ji}, \Delta MT_{ji}, \Delta LT_{ji}} (\Delta INC_i - \Delta CF_i)$$

- **Change in cost of funding:**

$$\Delta CF_i = r_i^D * \Delta D_i + r_i^{STS} * \sum_j \sum_k \Delta STS_{ijk} + r_i^{MTS} * \sum_j \sum_k \Delta MTS_{ijk} + r_i^{ST} * \sum_j \Delta ST_{ij} + r_i^{MT} * \sum_j \Delta MT_{ij} + r_i^{LT} * \sum_j \Delta LT_{ij} + r_i^{STSCB} * \sum_k \Delta STSCB_{ik} + r_i^{LTSCB} * \sum_k \Delta LTSCB_{ik} + r_i^{LTCB} * \sum_l \Delta LTCB_{il} + r_i^{SPCB} * \Delta SPCB_i$$

- **Change in net interest income:**

$$\Delta INC_i = r^R * \Delta R_i + \sum_j r_j^{STS} * \sum_k \Delta STS_{jik} + \sum_j r_j^{MTS} * \sum_k \Delta MTS_{jik} + \sum_j r_j^{ST} * \Delta STS_{ji} + \sum_j r_j^{MT} * \Delta MT_{ji} + \sum_j r_j^{LT} * \Delta LT_{ji}$$

2. Model in more detail: constraints

- **All deposit outflows need to be accounted for:**

$$\Delta D_i = \Delta R_i - \sum_j \left(\sum_k (\Delta STS_{ijk} + \Delta MTS_{ijk}) + \Delta ST_{ij} + \Delta MT_{ij} + \Delta LT_{ij} \right) - \sum_k (\Delta STSCB_{ik} + \Delta LTSCB_{ik}) - \sum_l \Delta LTCB_{il} - \Delta SPCB_i$$

- **Banks have a limited stock of excess reserves:**

$$R_i - MRR * \Delta D_i + \Delta R_i - \sum_j (\sum_k (\Delta STS_{jik} + \Delta MTS_{jik}) + \Delta ST_{ji} + \Delta MT_{ji} + \Delta LT_{ji}) \geq 0$$

- **Banks have a limited stock of unencumbered HQLA collateral**

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

- **Banks have a limits stock of unencumbered eligible non-HQLA collateral**

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

2. Model in more detail: liquidity coverage ratio

- **Banks must meet the LCR requirement, possibly sustaining a voluntary buffer**

$$LCR_i \geq 100\% + vol\_LCR\_buffer_i$$

- **The change in high quality liquid assets (HQLA, numerator of LCR) equals**

$$\Delta HQLA_i = \Delta R_i^{TOT} - \sum_j \sum_k \frac{(1 - LCR\ factor_k)}{(1 - haircut\ c_k)} * (\Delta STS_{ijk} + \Delta MTS_{ijk} + \Delta STSCB_{ik} + \Delta LTSCB_{ik}) + \sum_j \sum_k \frac{(1 - LCR\ factor_k)}{(1 - haircut\ c_k)} * (\Delta STS_{jik} + \Delta MTS_{jik}) + \psi_{LTL} * \Delta LTL_{ji}$$

- **The change in net expected outflow (E[net outflow], denominator of LCR) equals**

$$\Delta E[net\ outflow]_i = \Delta D_i * run\ off\ rate\ D_i + \sum_{f=STS,MTS,STSCB,LTSCB} \sum_j \sum_k (\Delta f_{ijk} * run\ off\ rate\ f_{ijk} - \Delta f_{jik} * inflow\ rate\ f_{jik})$$
$$+ \sum_{f=LTCB} \sum_j \sum_l (\Delta f_{ijl} * run\ off\ rate\ f_{ijl} - \Delta f_{jil} * inflow\ rate\ f_{jil}) + \sum_{f=ST,MT,LT,SPCB} \sum_j (\Delta f_{ij} * run\ off\ rate\ f_{ij} - \Delta f_{ji} * inflow\ rate\ f_{ji})$$

2. Model in more detail: net stable funding ratio

- **Banks must meet the NSFR requirement, possibly sustaining a voluntary buffer**

$$NSFR_i \geq 100\% + vol\_NSFR\_buffer_i$$

- **The change in available stable funding (ASF, numerator of NSFR) equals**

$$\Delta ASF_i = \Delta D_i * ASF\ factor\ D_i + \sum_{f=STS,MTS,STSCB,LTSCB} \sum_j \sum_k \Delta f_{ijk} * ASF\ factor\ f_{ij} + \sum_{f=LTCB} \sum_j \sum_l \Delta f_{ijl} * ASF\ factor\ f_{ij} + \sum_{f=ST,MT,LT,SPCB} \sum_j \Delta f_{ij} * ASF\ factor\ f_{ij}$$

- **The change in required stable funding (RSF, denominator of NSFR) equals**

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

3. Model in more detail: interbank market

- **Each banks borrow and lending choices must be consistent with aggregate market clearing conditions**

$$\sum_i \sum_j \Delta STS_{ij} = \sum_j \sum_i \Delta STS_{ji}$$

$$\sum_i \sum_j \Delta MTS_{ij} = \sum_j \sum_i \Delta MTS_{ji}$$

$$\sum_i \sum_j \Delta ST_{ij} = \sum_j \sum_i \Delta ST_{ji}$$

$$\sum_i \sum_j \Delta MT_{ij} = \sum_j \sum_i \Delta MT_{ji}$$

$$\sum_i \sum_j \Delta LT_{ij} = \sum_j \sum_i \Delta LT_{ji}$$

3. Model reflections

1. **No central bank asset purchasing** programmes as they are not an active choice of the bank but of the central bank
2. **Banks cannot sell assets** to obtain additional reserves as the subsequent redistribution of reserves and impacts on the various constraints are very similar to those resulting from secured interbank market funding
3. **No liquidity provision by non-banks** as the impact on the redistribution of reserves is the same whether reserves are exchanged directly between banks or indirectly at the request of a non-bank customer of a bank

Outline

3. Data

- **Time period**: Q3 2021
- **Data sources:** FINREP and COREP supervisory reporting data
- **Sample**: 2319 banks, representing >95% of total assets of supervised institutions
- **Data fields:** retail deposit funding (stable vs other), excess reserve and cash holdings, unencumbered HQLA (fourteen categories) and non-HQLA eligible collateral, Net E[outflow], ASF, RSF,
- Our general model could be simplified and applied using less granular data

3. Deposit outflow

- The model can accommodate any vector of expected bank-level deposit outflows
- **We do not estimate expected digital euro demand** and subsequent deposit outflows
- We calculate the maximum applicable CBDC demand for a range of holding limits:
  1. Multiply holding limit by the euro area population of 340 million to get the maximum aggregate deposit outflow
  2. Divide the maximum aggregate deposit outflow for a given holding limit by aggregate retail deposits in the banking system to obtain the share of total retail deposit funding that is withdrawn
  3. Calculate each bank’s absolute deposit outflow by multiplying the amount of its retail deposits with the share of total retail deposit funding in the banking system that is withdrawn.

➢ Extremely **conservative mapping of holding limits to deposit outflows**

3. Interest rates

- We do not use the interest rates observed in Q3 2021 due to TLTROs and excess liquidity
- Assume interest rates coherent with a reduction in excess reserves and well functioning markets, abstracting from unconventional central bank lending programmes.

Interest rates used in the application

r^{R}	-0.50% (DFR)	r^{STSCB}	0.0% (MRO rate)
r^{STS}	-0.40%	r^{LT}	0.10%
r^{ST}	-0.30%	r^{LTSCB}	0.20%
r^{MTS}	-0.20%	r^{LTCB}	0.20%
r^{MT}	-0.10%	r^{SPCB}	0.50%

3. Preference for liquidity buffers

- Observed LCR and NSFR values range from 102% to 600% as banks have heterogenous liquidity preferences
- Consider three liquidity risk tolerance scenarios:
  A. sustain 0% of current voluntary buffer
  B. sustain 50% of current voluntary buffer
  C. sustain 100% of current voluntary buffer
- **Scenario B is our baseline scenario** as it approximately coincides with incomplete data on internal liquidity targets and with the observed median annual change to liquidity ratios

3. Other

- Regulatory parameters (many) following the Basel regulations
- Minimum reserve requirement of 1% of deposits
- Assume that all HQLAs can be used as collateral on the interbank market and at the central bank
- Haircuts on HQLAs and non-HQLA collateral consistent with the European Central Bank’s collateral framework
- Assume equal haircuts to HQLAs in both the interbank market and at the central bank

Outline

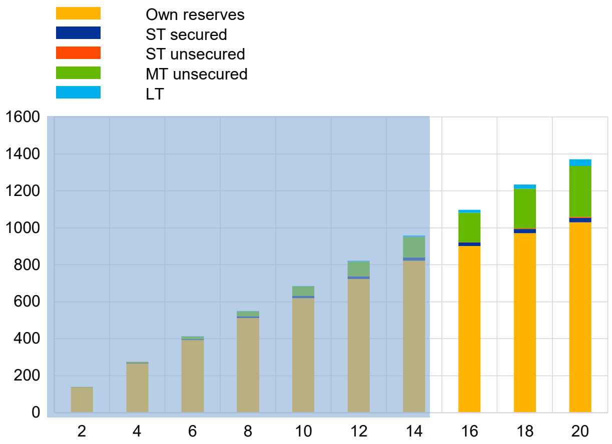
1. Summary of results for the euro area

- In our baseline scenario, if a digital euro was introduced in Q3-2021 with a €3.000 holding limit per person:
  1. Almost all banks could rely on their excess reserves to meet digital euro demand
  2. The Eurosystem would not have needed to provide additional reserves
  3. Bank balance sheets and liquidity risks would not have drastically changed
- At the time, concerns could arise only after deposit outflows possibly but highly unlikely with a holding limit of €6.000.
- We show that that the impact depends on prevailing macro-economic environment and that our conclusions are robust to a lower excess liquidity scenario and a bank run scenario.

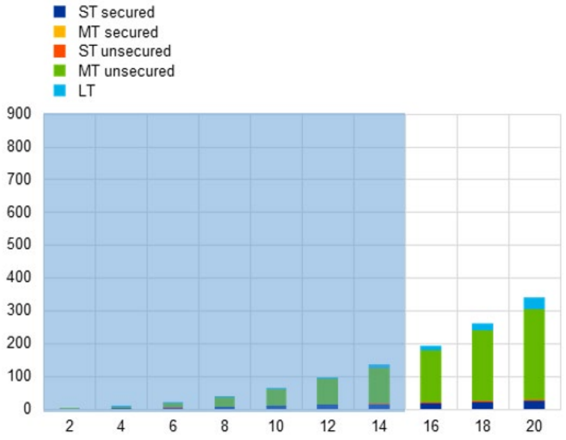
Excess reserves and its distribution

- Most outflows are replaced by lower excess reserves, leading to small IBM volumes
- Most market funding is medium-term unsecured funding, the cheapest source of funding which does not negatively affect LCR

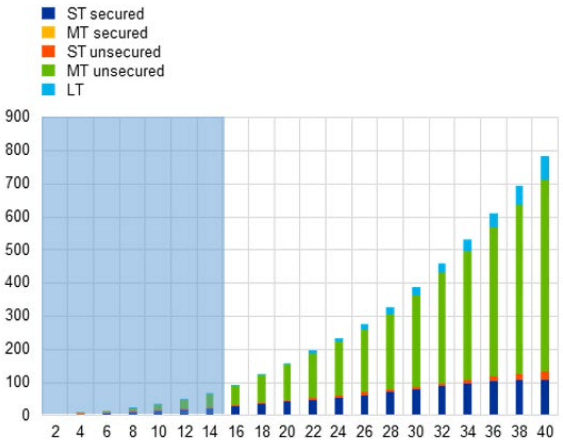
Scenario B



Scenario B



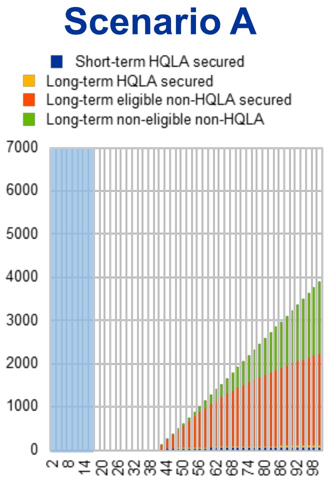
Scenario A

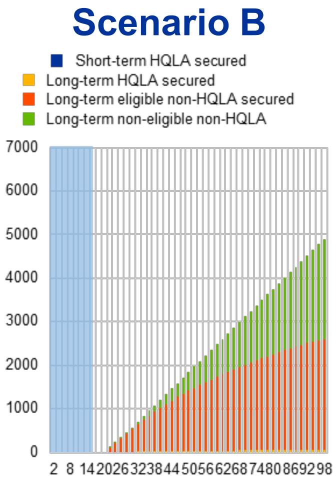


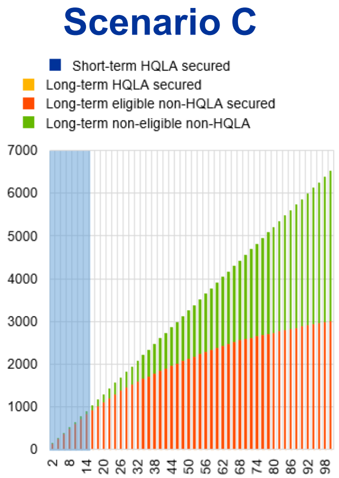
Notes: The amounts of interbank market funding per type of funding (in billon €) for a given deposit outflow (in % of retail deposits). The shaded area represents the possible share of deposit outflows in the event of a €3,000 holding limit.

The Eurosystem’s balance sheet

- Additional central bank funding only after the interbank market has insufficient liquidity
- **Baseline scenario B**: central bank funding at outflows larger than 20%, worth €1.4tn
- Almost no role for short-term and long-term HQLA secured CB lending



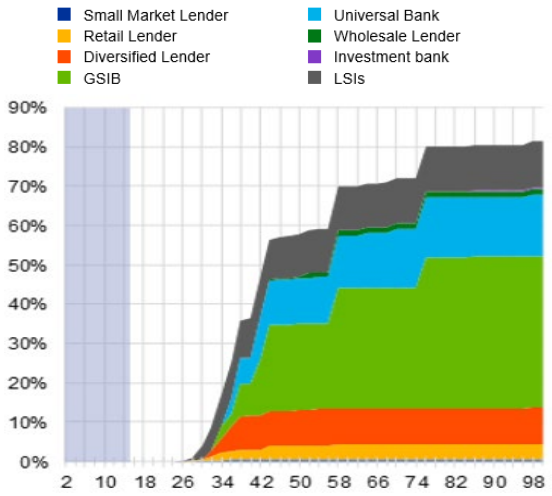




Notes: the amounts of central bank funding per type of funding (in billon €) for a given deposit outflow (in % of retail deposits). The shaded area represents the possible share of deposit outflows in the event of a €3,000 holding limit.

Central bank funding reliance

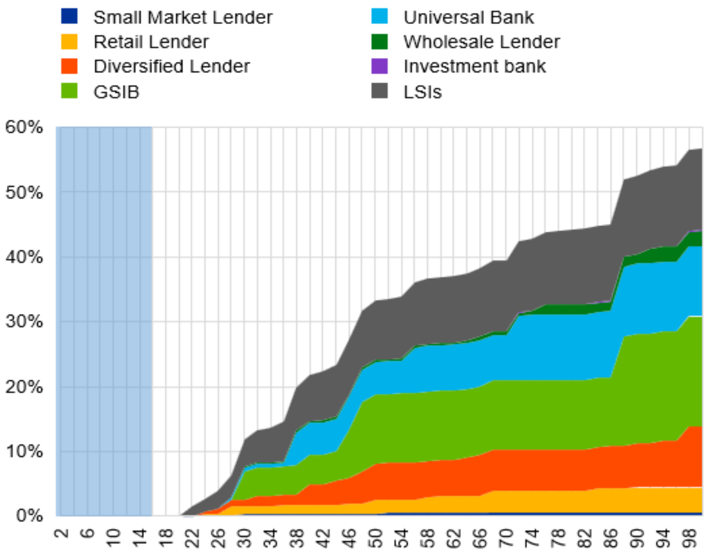
- At very high deposit outflows, reliance on the central bank becomes unusually large for many banks



Notes: Major ratio increases are those changes which are above the 90th percentile of quarterly central bank funding ratio increases observed since 2016. The shaded area represents the possible outflows in the event of a €3,000 holding limit.

Availability of eligible collateral

- At very high outflows, especially smaller banks would have had insufficient elligible collateral



Notes: share of total banking sector assets of banks with insufficient eligible collateral for central bank funding for a given proportion of retail deposit outflows. The shaded area represents the possible share of deposit outflows in the event of a €3,000 holding limit.

Outline

Alternative model specifications

- We consider t**hree alternative specifications** in the paper:

1. An environment with lower excess reserves

2. An interbank market segmented across national borders

3. Withdrawal of household deposits during a bank run

Outline

Conclusion

- We propose a methodology to quantify the impact of CBDCs and related policy choices on banks' liquidity risk and central bank reliance
- We use the model to illustrate the impact of a hypothetical digital euro introduction
- The simulated impact depends on the prevailing macroeconomic environment, especially on the distribution of excess reserves and unencumbered collateral
- **Our model could inform the calibration of a CBDC holding limit**

Many thanks for your attention.

Annex: Retail deposit outflows in relative (%) and absolute amounts (€bn)

Table 3

Converting percentage deposit outflows into euro

(EUR billions)

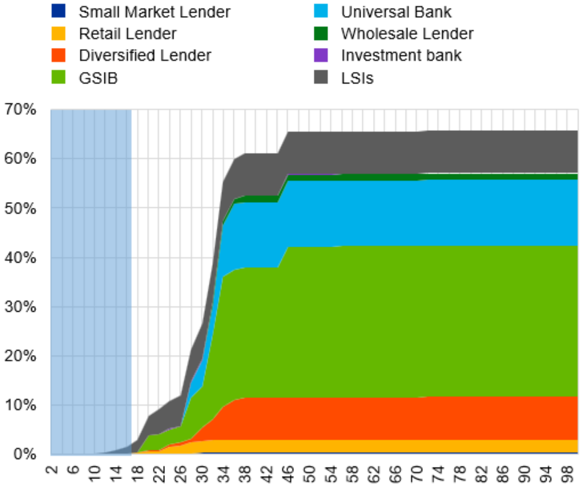
Outflow	1%	5%	10%	15%	20%	25%	30%	35%	40%
Q3, 2021	68.6	343	686	1,029	1,371	1,714	2,057	2,400	2,742
Q3, 2019	58.3	292	583	875	1,166	1,458	1,749	2,041	2,332

Data: own calculation using supervisory data.

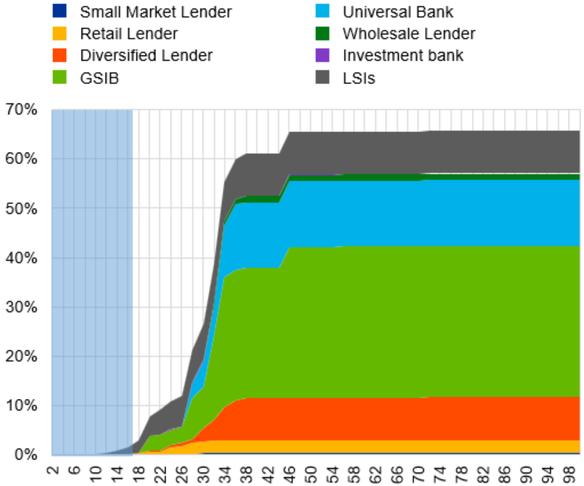
Annex: Impact on banks: wholesale funding reliance

- Banks that would have had an exceptional high increase in wholesale funding reliance

Scenario B



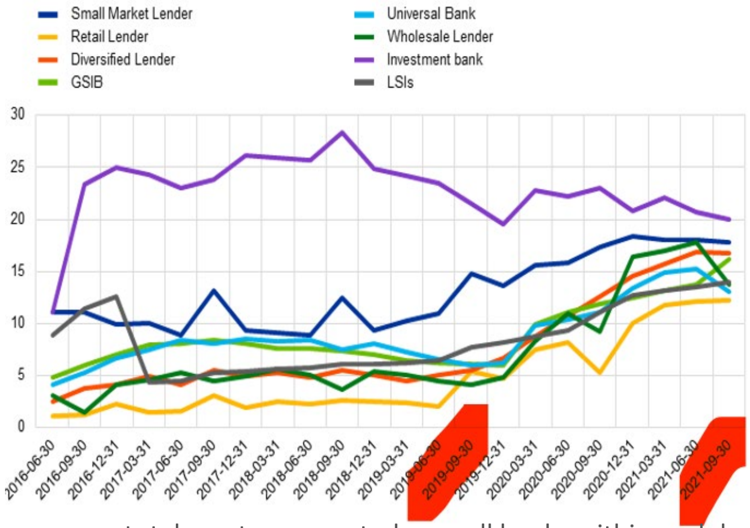
Scenario A



For scenario A, the share of total banking sector assets per business model of those banks whose increase in wholesale funding ratio is larger than 90% of quarterly increases since 2016, for a given deposit outflow, per business model

Annex: An environment with lower excess reserves

- In Q3 2021 excess reserves were exceptionally high
- What if a digital euro introduction takes place with less excess reserves in the system?
- Excess reserve ratio was 14% Q3 2021 versus 6% in Q3 2019



The sum of reserves over total assets aggregated over all banks within each business model group

Annex: An environment with lower excess reserves

Key findings using Q3 2019 data and considering a 3000 euro holding limit:

1. In our baseline case B, banks do require some additional Eurosystem funding under worst case outflows
2. Lower reserve ratio goes hand-in-hand with more available collateral and lower central bank funding reliance
3. Impact on balance sheet ratio’s not unusual, in levels or in changes

Annex: An interbank market segmented across national borders

- Alternative to “perfect interbank market”: segmented across national borders

Key findings:

1. No negative outliers: no national banking system requires additional reserves at a much lower outflow

2. Some positive outliers: banks in BE, LU and CY have sufficient reserves in the national banking sector to accommodate the outflow of all ON HH deposits

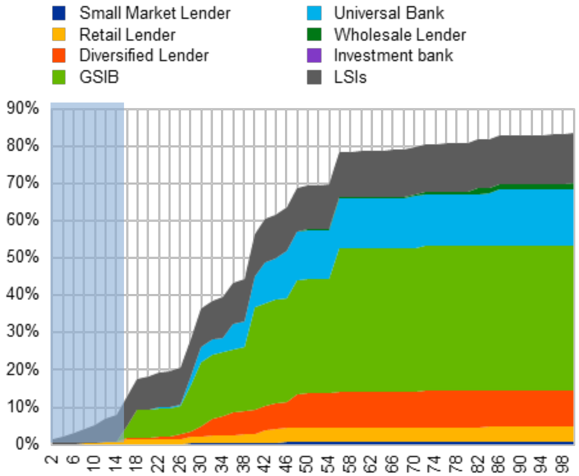
Annex: Withdrawal of household deposits during a bank run

- Bank run assumptions that simplify the model
  - No access to interbank market
  - Liquidity buffers can be used fully (below regulatory requirement)
  - Banks cannot obtain funding from Eurosystem if they have excess reserves
- Simplified model mechanics:
  1. First, a bank uses all its reserves.
  2. Next, it obtains additional reserves via regular open market operations.
  3. Once it has no reserves and no collateral, it would require Emergency Liquidity Assistance (ELA)

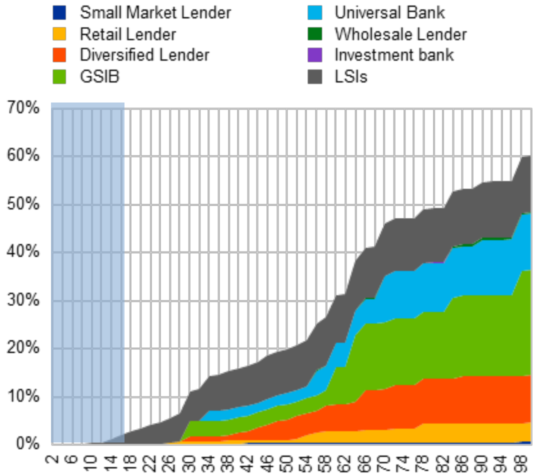
Annex: Withdrawal of household deposits during a bank run

- Under worst case aggregate digital euro outflows, liquidity risk contained
- Note that we ignore additional deposit outflows towards cash

Liquidity risk

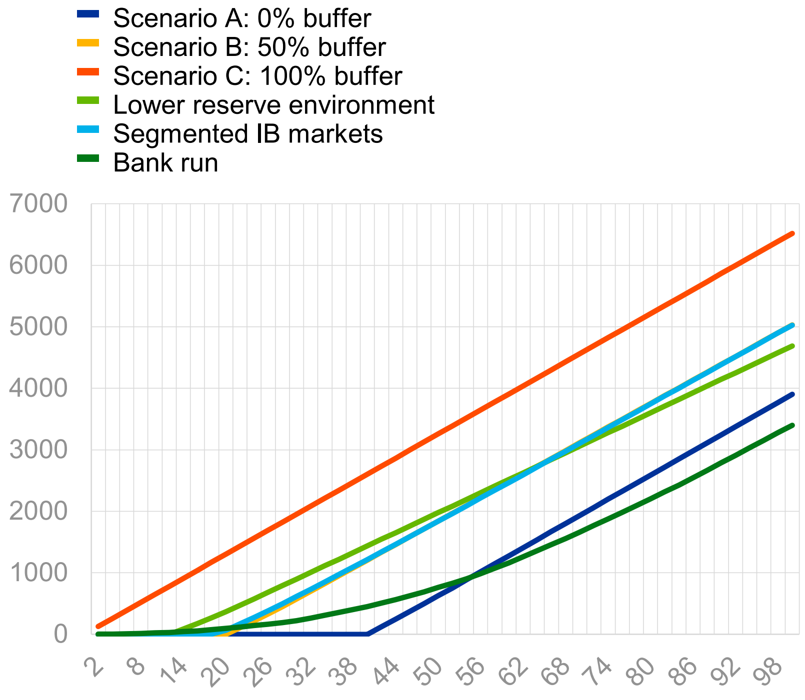


ELA

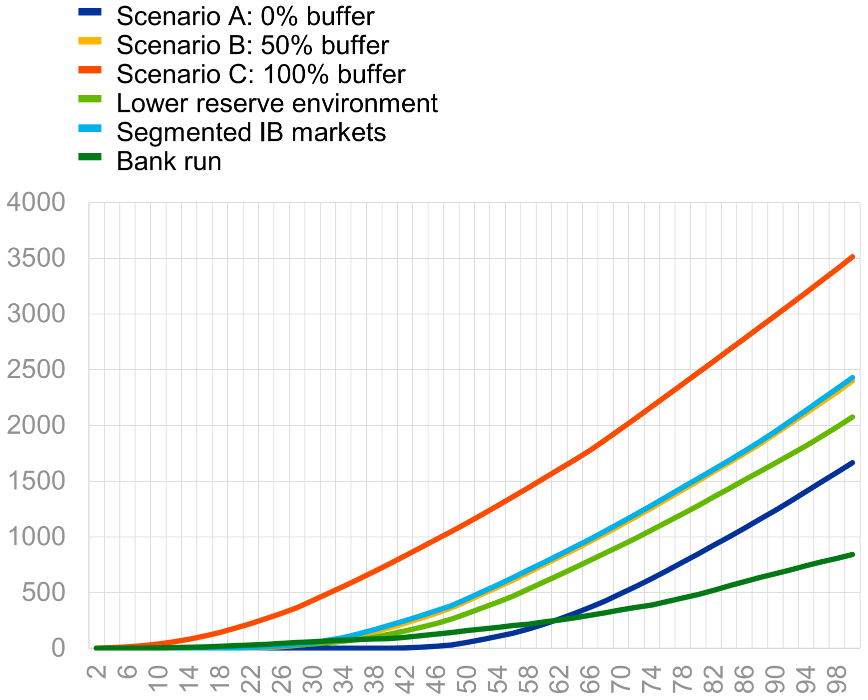


Left figure: the share of total banking sector assets of those banks whose LCR or NSFR would have fallen below the regulatory minimum of 100%.
Right figure: banks that would not have had sufficient reserves nor sufficient ECB-eligible collateral therefore would have needed ELA.

Annex: Summary of demand for central bank reserves



Reserve demand (in €bil) for given share of HH ON deposit outflow



… of which against ineligible collateral (in €bil)

Annex: summary of impact on banks

Deposit outflows for which banks worth more than 10% of the banking system's total assets…		Baseline			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
Bank run (banks on their own)	...breach liquidity requirement		16%		6%	same as baseline
	...need ELA: illiquid and no eligible collateral (1st SI needs ELA)		30% (14%)		32% (18%)	same as baseline
Orderly introduction (with interbank market and monetary policy operations)	…experience a WSF ratio increase>90% of historical quarterly (annual) changes	24% (100%)	28% (100%)	100% (100%)	100% (100%)	26% (100%)
	…experience a CBF ratio increase>90% of historical quarterly (annual) changes	50% (60%)	34% (44%)	16% (28%)	28% (40%)	32% (42%)
	…do not have sufficient ECB-eligible collateral	50%	30%	12%	38%	30%