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Staff Memo

Liquidity risk in the banking system – a new model and a stress test with a cyber scenario

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Financial stability, cyber risk, liquidity risk, banks, stress tests

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Norges Bank has developed a model for liquidity stress testing. The model is used to assess banks' vulnerabilities and resilience. The 2024 stress test illustrates how a hypothetical cyber attack could affect banks' liquidity. The results were published in *Financial Stability Report* 2024 H1 showing how such analyses can be utilised and indicating that Norwegian banks can tolerate large withdrawals of deposits.

1. Introduction[1]

For households and firms to be able to pay, save, borrow money and hedge against financial risk, the financial system must be well-functioning and stable. Potential disruptions include rapid fluctuations in market prices, recession or cyber attacks. Liquidity risk is a key risk for banks. If banks' liquidity risk is too high and cannot be managed, shocks may trigger turbulence and financial crises, which in turn may entail substantial costs to the economy.

The likelihood of a sophisticated cyber incident threatening financial stability has gained increased relevance and attention in recent years, but the basis for analysis remains inadequate. In many cases, any systemic effects of a cyber incident in the financial system will impact banks' liquidity. Norges Bank's model enables the analysis of systemic effects of liquidity stress arising from such events as a serious cyber incident. This may be a useful tool for identifying and assessing banking sector vulnerabilities and resilience.

Norges Bank "promotes the stability of the financial system", "to ensure that the financial system is able to absorb shocks so that it can function efficiently in both normal and turbulent times" and "monitors the financial system as a whole, with particular focus on the risk of systemic failure".[2] In the event of a crisis or turbulence in the financial system, Norges Bank may provide banks with extraordinary liquidity loans. It is therefore particularly important for Norges Bank to monitor and analyse liquidity risk in the banking system. The liquidity stress testing model is a useful framework in both oversight and preparedness work.

This Memo is structured as follows: Section 2 discusses banks' liquidity risk, Section 3 describes the 2024 stress test scenario and how a cyber attack may lead to a loss of confidence in banks and bank runs. Section 4 summarises the model set-up, while Section 5 discusses potential model applications in Norges Bank's work to promote financial stability.

[1] Thanks to Amund Tandberg, Joakim Rolfsøn, Espen Green, Ylva Søvik, Sindre Weme, Torbjørn Hægeland, Ragna Alstadheim and Ingvild Vestad for useful comments.
[2] See Norges Bank (2024d) p. 2.

2. Liquidity risk

Banks play a key role in society and the financial system. They redistribute risk and enable households and firms to save and make payments.[3] In addition, most of the credit in the Norwegian economy consists of loans from banks.

Liquidity risk in banks

Liquidity risk is the risk that banks are unable to meet their obligations when due. Banks' liquidity risk is a key risk in the financial system.

The term *liquidity* may refer to[4]:

- Funding liquidity: whether banks can obtain funding at an acceptable price to service maturing debts and pay other expenses. New funding can be both wholesale funding and deposit funding.
- Market liquidity: whether securities and other assets in the market can be traded without causing large price fluctuations.
- Central bank liquidity: banks' deposits at the central bank.

Banks contribute to maturity transformation in the financial system by enabling customers to borrow at long maturities, while depositors nevertheless have ongoing access to their funds. This entails liquidity risk for banks: they need to replace deposit outflows and other funding due before the loans are repaid. At the same time, the maturity transformation provides economic gains. For example, short or non-maturity deposits can finance long-term investments and growth in the economy. Firms can borrow to invest in production equipment and repay the loan over a longer period with future income from production. Maturity transformation gives households the corresponding opportunity to invest in housing and smooth consumption over time. The aim should therefore not be for banks to achieve minimal liquidity risk.

At the same time, resilient banks are crucial for financial stability. Banks are the only financial institutions that can accept deposits from firms and individuals, and deposits are the most important source of funding for Norwegian banks.[5] Even deposits without a lock-in period are normally considered stable funding since individuals and firms need to keep a certain level of deposits to cover expenses. Fluctuations in the accounts of individual customers will also be smoothed in aggregate. However, situations may arise in which many customers choose to withdraw deposits quickly from a bank at the same time, a so-called "bank run".

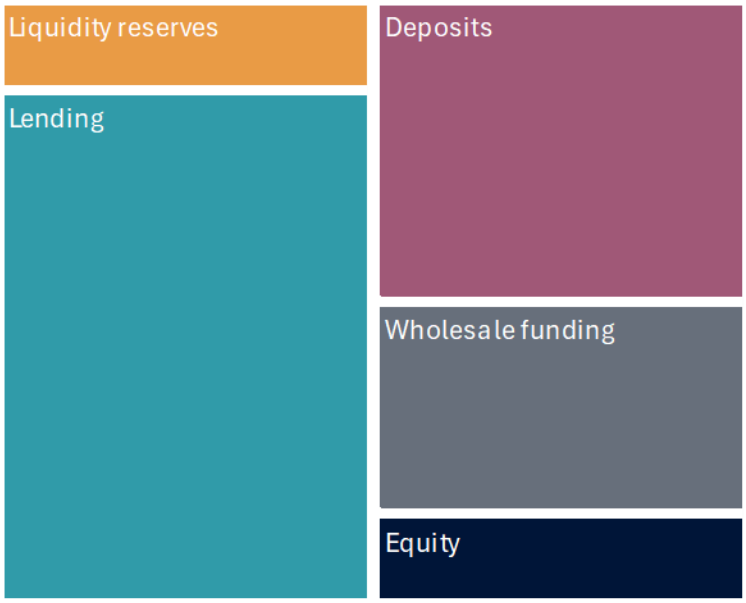
This can lead to liquidity problems for banks. The banking turmoil in the US and Credit Suisse in spring 2023 served as a reminder that deposits can be volatile and that bank runs can occur very quickly. Banks' business models indicate that only a share of deposits is offset by central bank money and other liquidity reserves (Chart 1), reflecting inherent liquidity risk in banks.

In the event of a bank run, the impact on securities markets may be considerable. If several banks lose deposits and need to obtain liquidity by selling securities from their liquidity reserves at the same time, this may trigger

[3] See Norges Bank (2024a).
[4] For a more detailed description, see *Norway's Financial System* 2024, p.19, Norges Bank (2024a).
[5] See Norges Bank, (2024d).

fire sales, greatly impacting prices and leading to a reduction in the value of liquidity reserves. Market liquidity of securities held in banks' liquidity reserves is therefore also of importance for banks' liquidity risk.

Chart 1 – Stylised bank balance sheet



Other funding may also entail liquidity risk. Wholesale funding such as bonds or notes, often with shorter maturities than banks' assets, can result in refinancing risk. Financial market turbulence or weakened confidence in a bank may result in investor reluctance to renew funding and liquidity problems at the bank.

Liquidity problems tend to arise quickly and there may therefore be little time for banks and authorities to take action. The problems will often spread between banks and other financial system participants, partly because they are dependent on each other for liquidity redistribution. The redistribution takes place in the money market, where participants trade with each other to control liquidity variation.[6] Moreover, banks are interconnected through interbank exposures and common or similar securities in their liquidity reserves.[7] Banks are also often dependent on the same funding markets, and if many banks are simultaneously affected by bank runs or market turbulence occurs, this may lead to systemic liquidity problems.

Liquidity crises occur rarely and often unfold differently from crisis to crisis, but they can have major consequences. This makes it particularly important to monitor banks' liquidity with a view to promoting financial stability. By identifying risks, measures can be taken to prevent banks from losing access to funding, strengthen resilience to liquidity problems and to counteract contagion between banks and other financial institutions.

[6] See Stiansen, K. (2022).
[7] See Norges Bank (2024d).

Regulation of liquidity risk

It is important that banks can carry out their tasks in the financial system without interruption and thereby contribute to economic stability. Liquidity risk regulation contributes to continuity by preventing excessive risk-taking and by ensuring resilient and well-functioning banks.

Rational actions taken by individual participants may be detrimental to the wider system, which can worsen liquidity problems. For example, banks in the money market can "hoard" liquidity in uncertain situations, thereby exacerbating problems and contributing to reduced liquidity redistribution. Depositors can choose to withdraw deposits if confidence in a bank is weakened, thereby contributing to a deterioration in the bank's funding situation, which in turn can spread to other banks. Banks can resort to securities fire sales to provide liquidity and thereby contribute to a sharp fall in the value of their own and other banks' liquidity reserves. Banks can also choose to tighten lending to customers to improve their liquidity situation, thereby worsening a possible downturn in the economy.

Although such behaviour may be rational and remedial for each individual participant in the short term, it may intensify liquidity problems for other participants and for the individual in the longer term. An expectation that central banks will step in quickly to resolve the problems may lead to moral hazard. Conflicting interests between individual participants and the wider financial system, as well as moral hazard, make regulating banks important.[8]

After the financial crisis, a new liquidity regulation was introduced, based on Basel standards. The Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR) are crucial requirements banks must meet.[9]

Banks' internal risk management and supervision of banks are essential for limiting the amount of liquidity risk that individual banks take. Finanstilsynet (Financial Supervisory Authority of Norway) plays an important role in ensuring risk awareness and is responsible for supervision related to banks’ risk management and control.[10]

The deposit guarantee scheme is also a key regulation that promotes confidence.[11] The scheme guarantees that individuals and firms can safely deposit their money in banks, thereby reducing the risk that many people will withdraw money at the same time. This helps to reduce banks' liquidity risk.

If situations arise where a bank encounters liquidity problems, the central bank may provide liquidity support. Norges Bank can provide extraordinary liquidity to the entire banking system or to individual banks when access to liquidity from other sources is impaired.[12]

[8] See also Borchgrevink, Søvik, and Vale (2013) and Søvik (2020).
[9] For more detailed information on the regulations, see Annex 2 – Regulation of capital and liquidity in *Norway’s financial system* 2024, Norges Bank (2024a).
[10] See Finanstilsynet (2022).
[11] See The Norwegian Banks’ Guarantee Fund (2024).
[12] See Norges Bank (2024b).

3. An adverse cyber scenario in the liquidity stress test

For several years, Norges Bank has pointed out that the Norwegian financial system is vulnerable to severe cyber attacks. Concentration, complexity and interconnectedness may amplify the consequences of a cyber attack that then spreads quickly to the wider financial system. We therefore need analyses and discussions of how the consequences of a cyber attack may develop, for example how it may lead to financial problems for banks and general financial turbulence.

The IMF refers to cyber attacks as a growing threat to financial stability and a potential source of banks' funding problems.[13] Chapter 3 of the IMF's *Report* contains, among other things, an empirical analysis of deposit movements following cyber attacks in US banks. The analysis shows moderate and somewhat persistent deposit withdrawals in the quarters following a cyber attack, which illustrates that cyber attacks may affect banks' deposits. Duffie and Younger argue that it is conceivable that deposit outflows can be both substantial and abrupt in the event of more severe cyber attacks.[14]

Sound contingency arrangements may mitigate the consequences of a cyber attack, and to date, cyber incidents have not given rise to financial instability, either in Norway or abroad. Norwegian banks are continuously working to maintain and enhance their defences against cyber attacks, and most attacks are averted before they impact banks' customers.[15]

In addition to individual banks' work on their own cyber security and contingency planning, cooperation and measures at the sector level are key.[16] Measures that reduce the likelihood that customers will not be able to pay for goods and services could mitigate the effects of a cyber attack. An example is the Norwegian financial sector's collaborative backup solutions for cards and payment terminals. Households' contingency arrangements, for example holding an account at several banks or having some cash available, also helps to maintain the ability to pay for goods and services in a situation where deposits in individual banks become unavailable.

The cyber scenario

The liquidity stress test was used in *Financial Stability Report* 2024 H1 as a framework for assessing how a cyber attack could affect banks' liquidity and funding.[17] In financial stress tests, a cyber attack as a scenario is a new angle, and few central banks have so far published similar analyses.[18] Limited information and a new model mean that the mechanisms and assumptions in the stress test are uncertain.

[13] See IMF (2024).
[14] See Duffie and Younger (2019).
[15] See Finanstilsynet (2024).
[16] See Norges Bank (2024c).
[17] See Norges Bank (2024d).
[18] The Dutch central bank also uses a cyber attack scenario for withdrawing deposits, see De Nederlandsche Bank (2022).

We assume a scenario in which a key IT service provider for the Norwegian banking sector is subjected to a cyber attack. The service provider is responsible for the operation of core banking systems and payment services for several Norwegian banks. In the scenario, one consequence is that bank customers largely lose access to card payments, Vipps, ATMs and online and mobile banking for an entire week. In the past, adverse events have had similar effects, albeit for shorter periods. After the first week of the scenario, uncertainty is also amplified by unstable account access and customer account balances that do not match pre-attack levels.

It is difficult to know how customers and creditors would react to such a serious cyber incident with long-lasting consequences. In this scenario, we envisage large consequences for confidence in the affected banks, which in turn leads to bank runs when access is restored.

Bank runs

Weakened confidence may be a substantial cause of systemic financial problems for banks. A loss of confidence may occur both owing to concern about a bank's financial position or to operational problems that make deposits unavailable. The cyber scenario in *Financial Stability Report* 2024 H1 is an example of the latter.[19]

It is easier for a bank to deal with large deposit withdrawals if the deposits disappear at a slow pace than if they disappear quickly. The faster the pace, the faster the bank's financing problems materialise. Measures the bank can implement, such as raising new funding, selling assets or scaling down lending, can take time. Measures taken by the authorities may also be more difficult to implement if the deposits disappear quickly.

There may be several reasons why bank runs can occur faster now than before. Some argue that bank runs are now faster than before because of digital payment solutions and instant payments.[20] Others argue that large corporations, which were the main drivers of bank runs in some US banks in 2023, already had the opportunity to move deposits easily in the 1970s, and that there is little indication that depositors in 1984 or 2008 had to wait for several days to withdraw deposits because of technical limitations.[21]

Continuous access to deposit information via mobile apps can also speed up deposit withdrawals. Operational problems that arise and disrupt customers' access to check balances at will, can reinforce the loss of confidence and lead to more customers moving deposits quickly when access returns. Digitalisation of customer services may also have led to customers having accounts with several banks. This simplifies the process of moving deposits between banks, resulting in a greater inclination of customers to move deposits in response to uncertainty regarding one of their banks. The same applies if customers do not feel a particular affiliation with a bank or if bank deposits appear to be a standard commodity. There may then be a lower threshold for switching banks.

[19] See Norges Bank (2024d).
[20] See, for example, the Financial Stability Board (2023) and Group of Thirty (2024).
[21] See Rose (2023).

Information sharing via social media can contribute to a faster loss of confidence and withdrawal of deposits. Disinformation and misinformation can also contribute to increased turbulence and depositor flight from banks that are not initially in trouble, but which eventually nevertheless experience liquidity problems as a negative feedback loop occurs.

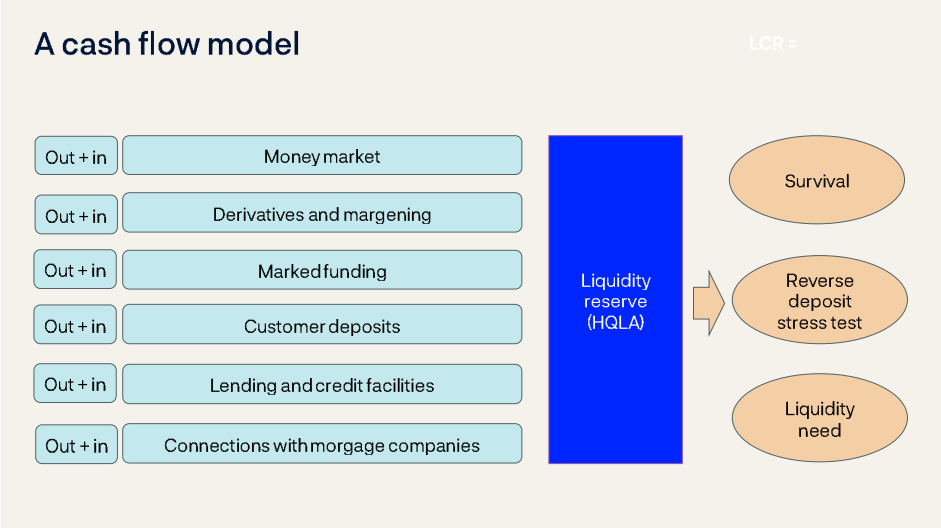
4. Liquidity stress testing model

We have developed a model for liquidity stress testing of banks. The purpose of the stress test is not to calculate exact outcomes, but rather to structure discussions and assessments of banks' liquidity and funding using scenarios and sensitivity analyses.

The liquidity stress test is a simple cash flow model (Chart 2). We make assumptions about behaviour by specifying the size of incoming and outgoing payments related to various cash flows, balance sheet items and off-balance sheet items. Net payments are grouped as in Chart 2.

The model is based on the liquidity coverage ratio (LCR). The LCR is in itself a stress test that assumes incoming and outgoing payments over a 30-day stress period and requires banks to maintain a sufficient liquidity reserve to be able to cover net payments during this period.

Chart 2 – Models



Source: Norges Bank

Data

The liquidity stress test mainly uses data that banks report to Finanstilsynet. Data reporting requirements are specified in EU regulations, more specifically the CRD/CRR. We use reported LCR data and ALMM data (Additional Liquidity Monitoring Metrics). The data include banks' liquidity reserves, cash inflows and outflows in the event of a predefined stress scenario, and banks' contractual cash inflows and outflows. LCR data are reported monthly by all Norwegian banks, while ALMM is reported monthly by the largest banks and quarterly by

other banks. The model uses the "Maturity Ladder" part of ALMM, which shows contractual cash flows. Most other central banks use similar data in their liquidity stress tests.[22]

The model also uses data from banking statistics (ORBOF) and Finanstilsynet's annual RUS survey (Refinancing under stress). In the 2024 stress test, we used banks' reports from year-end 2023, aggregated for all currencies.

Stress test subjects

The model is designed to analyse Norwegian banks and their covered bond mortgage companies. Norwegian branches of foreign banks, such as Nordea and Danske Bank, are excluded from the stress test, partly reflecting insufficient branch data.

Liquidity does not necessarily flow freely between different legal entities in a group. The BIS therefore emphasises the inefficiency of stressing a bank in a consolidated manner and that stress tests should examine the parent bank in isolation.[23] By mapping intra-group obligations and constraints, it is possible to identify several factors that may trigger liquidity problems at the bank. This applies, for example, to internationally active banks, as was the case for Credit Suisse in 2023.[24] A bank may also have a liquidity need if the associated covered bond mortgage company draws on credit lines or triggers guarantee obligations due to, for example, a major fall in house prices, defaults or an inability to refinance. By using consolidated data, we will not capture such conditions to the same extent. In the model, we have nevertheless chosen to examine banks on a consolidated basis, ie together with the covered bond mortgage company. The liquidity situation may appear somewhat better by using consolidated data compared with the use of non-consolidated data.

The 2024 stress test included the seven largest Norwegian banks at year-end 2023 and their associated covered bond mortgage companies (DNB, SpareBank 1 SR-Bank, SpareBank 1 Nord-Norge, SpareBank 1 Østlandet, SpareBank 1 SMN, Sparebanken Vest and Sparebanken Sør). These are the same banks that are included in Norges Bank's solvency stress test.

The model stresses each banking group individually, and the stress test thus constitutes a collection of partial stress tests of individual banks. Although the model tests banks individually, it may be useful to look at several banks together, for example in assessments of total liquidity needs. The assumptions used in the stress test may reflect bank-specific stress, broader market stress, or a combination of these. In the 2024 stress test, the assumptions were calibrated according to a stress scenario that affects all the major banks at the same time.

Time horizon

The model enables the most appropriate time horizon to be chosen, in light of the scenario choice. Maturity ladder reporting covers all maturities, but segmentation becomes less fine-meshed over the horizon. Different central

[22] See, for example, the description of Sveriges Riksbank's liquidity stress test, Danielsson and Manfredini (2019).
[23] See BIS (2013).
[24] See BIS (2024).

banks have chosen different time horizons. For example, Sveriges Riksbank and the European Central Bank (ECB) use a six-month horizon[25], while the Bank of England has a ten-day horizon in its "System-wide exploratory scenario"[26].

In the 2024 liquidity stress test, we used a two-month time horizon with weekly time intervals until week 5. Primarily weekly intervals elucidate the consequences of a rapid bank run and how banks manage through the period, not just at the end of the horizon.

Cash flow assumptions in the 2024 stress test

In the 2024 stress test, we assumed that a cyber attack led to customers losing confidence in the seven largest Norwegian banks, and many chose to move deposits to other banks that did not experience serious operational problems. We can later use different narratives and scenarios when conducting liquidity stress tests, and thus different assumptions can be made.

A cyber attack can affect banks through multiple channels, but in the 2024 stress test, the analysis was limited to the confidence channel, which focuses on how deposit funding could be affected and the consequences for banks' liquidity. In order to carry out the analysis, assumptions about other balance sheet items and non-balance sheet items were made.[27] We based our assumptions on the idea that a stress test should be an improbable, albeit plausible, serious tail event.

A lack of empirical data makes it challenging to design liquidity risk models. Liquidity crises rarely occur, and authorities have often intervened with measures in liquidity crises, which disrupts the data. Historical data to calibrate assumptions for liquidity effects of cyber attacks are particularly lacking. In addition, confidence is difficult to measure. The assumptions in the 2024 stress test have been made based on assessments of available data and other qualitative information and are therefore uncertain. This limits how we can use the results of the stress test.

In the model, we assume that banks do not receive liquidity support from Norges Bank or support from authorities. This is in line with common practice for the design of stress tests.[28]

Deposit withdrawal assumptions

The model distinguishes between different categories of deposits, based on the reporting in LCR and ALMM. Different deposit withdrawals are assumed for different categories, ie the share of deposits that will disappear from the bank. The size of the withdrawals in each bank therefore varies depending on the bank’s type of deposit pool. All seven banks are assumed to be exposed to the same run-off rate in the different deposit categories, even though the model allows for different conditions for different banks. The deposits disappear from all seven banks at the same time, and the model does not specify to where the deposits are moved. This is intended to illustrate a situation where a group of

[25] See Danielsson and Manfredini (2019) and ECB (2019).
[26] See Bank of England (2024a).
[27] See Appendix.
[28] See BIS (2013).

banks face a bank run at the same time. Other banks, on the other hand, will have an influx of deposits. The assumptions used in the 2024 stress test for customer deposits have been summarised and compared with the assumptions in the liquidity regulation (LCR) in Table 1.

No fewer than 96% of Norwegians use digital banking services.[29] In addition, Norway is among the countries where bank customers use cards for payments most frequently, and many do not use cash.[30] Customers may therefore react faster to problems with access to account information or other banking services as a result of a cyber attack. Social and traditional media will probably also provide considerable coverage of the cyber attack and contribute to rapid information sharing among depositors.

Table 1 –Bank run assumptions

30-day withdrawal factor[1]	Cyberscenario FSR 2024 H1	In the liquidity regulation (LCR)
Retail/SME – *Guaranteed deposits*	20	5
Retail/SME – *Non-guaranteed*	33–50	10–16
Large firms – *Operational deposits*	15–40	5–25
Large firms – *Guaranteed*	40	20
Large firms – *Non-guaranteed*	50	40

1 Assumptions about percentage withdrawals of different deposit categories.

Norwegian retail and wholesale customers tend to have accounts at more than one bank, and it is easy to open an account at a new bank, especially for retail customers. This means that most people can quickly transfer their deposits to another bank. Usually, it only takes a few days for a firm to open an account at a new bank, depending on how complex the business is and what checks the bank needs to make under the anti-money laundering regulations. There may be slightly more restrictions on how easily firms can transfer operating accounts tied to other related systems in the firm, but they can quickly transfer surplus funds to another bank. Since we assume that the transfer of operational deposits is more time consuming, these deposits do not have the largest outflow until after a few weeks.

The Norwegian deposit guarantee scheme covers up to NOK 2m per depositor per bank, and these deposits are normally considered to be a stable source of funding for banks. Overall, around half of customer deposits at Norwegian banks are covered. The guarantee scheme provides solid insurance against deposit loss, which promotes confidence. Guaranteed retail deposits, which account for almost half of banks' customer deposits, result in lower liquidity outflows under the liquidity regulations (LCR) than non-guaranteed deposits. The same applies to guaranteed wholesale deposits, but the majority of wholesale deposits are non-guaranteed.

The guarantee scheme is designed for situations when a bank is liquidated under public administration, and the guarantee will therefore not be triggered by liquidity problems alone. In his speech from February 2024, Governor of the

[29] For the statistics, see ee Statistics Norway (2024).
[30] See Retail payment services 2023, Norges Bank (2024e).

Bank of England, Andrew Bailey, points out that in order to assume stable guaranteed deposits, customers must be confident that their deposits are always available.[31] The extent to which customers will choose to withdraw deposits covered by the deposit guarantee scheme will probably vary from scenario to scenario. In our scenario, where a loss of confidence from a cyberattack causes customers to lose access to their deposits for a period of time, it is conceivable that customers could also choose to move guaranteed deposits to ensure continuous access to their funds. We therefore assumed that some customers would move their money out of the bank in the period following resolution of the technical problems. The liquidity outflow from guaranteed deposits in the 2024 stress test is higher than in the liquidity regulations, but still lower than for non-guaranteed deposits.

Items excluding customer deposits

For items excluding customer deposits, the liquidity stress test for 2024 is largely based on the same assumptions as in the liquidity regulations (LCR).

In the model, banks use liquidity reserves to cover liquidity shortfalls resulting from net outflows. For the sake of simplicity, we have applied factors for haircuts on these reserves in the 2024 stress test, in line with the factors assumed in the LCR. See the Appendix for a brief summary of the assumptions about items excluding customer deposits.

5. Applications of the liquidity stress test

The liquidity stress test can be used for various purposes. First and foremost, the analyses can increase the understanding of financial system liquidity risk and thus be very useful in financial stability analyses. The model can provide information about banks' ability to handle different scenarios, help assess adequate bank resilience and be used exploratively to identify vulnerabilities and risks in the financial system.

Norges Bank's responsibility and role as lender of last resort require a sound understanding of banks' liquidity situation and how possible scenarios may play out. For Norges Bank to offer liquidity support, banks must provide sufficient collateral.[32] The stress test is a source of useful information for the assessment of banking sector liquidity needs in a crisis. The stress test can also provide information about Norges Bank's ability to provide liquidity support by estimating how much ordinary collateral banks will have available. The liquidity stress test therefore contributes to crisis preparedness.

Liquidity risk analyses

The scenario assumptions and model calculations provide different key figures and results. Compared to the LCR, the model is flexible. We can test for different assumptions and all cash flow assumptions can be easily adjusted. The model is also flexible in terms of time horizon. The LCR is a 30-day calculation, while in the model we can examine both shorter and longer time horizons. This

[31] See Bank of England (2024b).
[32] see Section 3-1, fifth paragraph of the Norges Bank Act (2019).

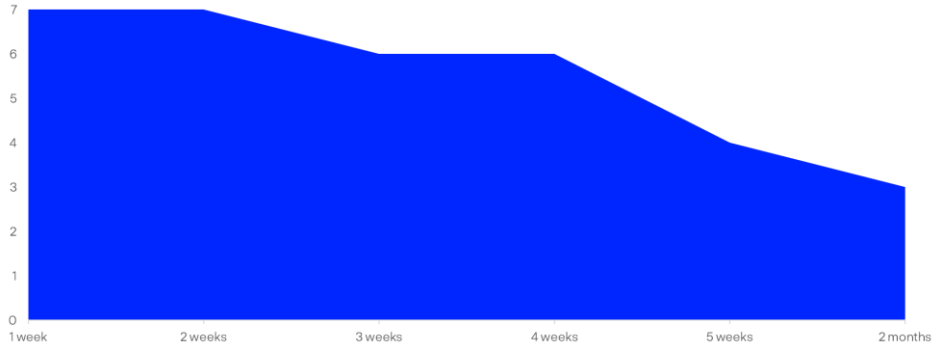
allows for the identification of whether the liquidity situation is also vulnerable at other times, leading to more information than from the LCR.

We can estimate survival horizons for different scenarios. Survival can be defined in different ways. We can, for example, assume that banks use all or part of their liquidity reserves, that they can make use of available cover pool to issue more covered bonds, or define different LCR levels for survival.

In *Financial Stability Report* 2024 H1, different results from the 2024 stress test are presented.[33] Among other things, the survival horizon was presented by examining how many banks had sufficient liquidity reserves to cover the sharp bank run assumed in the stress test (Chart 3).

Chart 3 – Number of banks with positive liquidity reserves

Number of banks with positive liquidity reserves after a bank run as a result of a hypothetical sophisticated cyber attack



Sources Finanstilsynet and Norges Bank

The chart shows the seven largest Norwegian banks individually and how long they can survive in the stress scenario before they have a negative liquidity position, ie they depleted their entire liquidity reserve. We assumed that about 15% of customer deposits are withdrawn in week 1, about 7% in week 2, and then a falling share up until two months. This gives a weighted deposit outflow of approximately 30% over a four-week period, and up to 40% after two months. The assumptions about stress related to other funding are as described earlier and in the Appendix. The results indicate that most banks have sufficient liquidity reserves to cover net outflows for at least four weeks. Liquidity reserves other than those defined as high-quality liquid assets (HQLA) in the LCR are not included and would have improved the estimated survival.

In addition, we can calculate the size of the run-off factors required for individual items before banks have exhausted their entire liquidity reserves or when they reach a set minimum level. Such "what ifs" can be particularly useful when we have little experience with behaviour and mechanisms. Less emphasis will then be placed on uncertain assumptions about individual items. Since we have no experience of how a sophisticated cyber attack may create liquidity problems for

[33] See Norges Bank (2024d).

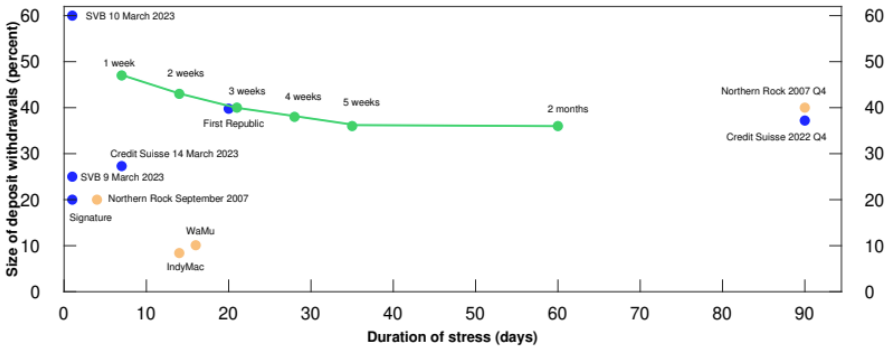
banks, it is difficult to assess how large a bank run we can expect and which run-off factors we should use in the model.

In *Financial Stability Report* 2024 H1, a reverse stress test for deposits was presented, based on the stress test model. We then calculated the magnitude of the bank run required for banks to exhaust their entire liquidity reserve at various times in a hypothetical stress scenario (Chart 4). The reason for the downward trend of the curve is the assumption that all other balance sheet items except deposits are also exposed to stress. There is therefore diminishing available liquidity to cover bank runs as time passes. Again, liquidity reserves other than what is defined as HQLA are not included. The exercise does not provide any information about the pace of bank runs.

If the bank run occurs one week into the stress scenario, the seven banks have accumulated enough liquidity reserves to cover a deposit outflow of approximately 45%, provided they use the entire remaining liquidity reserve. If the bank run takes place four weeks into the stress test, the banks can cover a deposit outflow of about 35%. Although it is difficult to predict how a bank run will turn out, it appears that Norwegian banks are well placed to cope with a severe bank run. At the same time, in such a situation, banks will face challenges before their liquidity reserves are fully exhausted, ie at lower levels of deposit outflows.

Chart 4 – Reverse stress test of deposits

Size and speed of previous bank run episodes and resilience of the largest Norwegian banks (green line) given different times for bank runs



Sources: Finanstilsynet, IMF and Norges Bank

Chart 4 also shows various episodes of bank runs during the banking turbulence in spring 2023 and during the global financial crisis in 2007 and 2008. There are many differences between these episodes. These banks differ according to business model and financing structure. The episodes are from different countries with different financial systems and regulatory regimes. Furthermore, the deposit guarantee schemes are different. Various measures have also been implemented by central banks and other authorities during the various episodes. Moreover, the triggering factors differ, and none of the historical episodes are triggered by a cyber attack with a subsequent loss of confidence. It is therefore not possible to use the episodes to calibrate our scenario or as an indication of the severity of an expected bank run resulting from a cyber attack. However, the

severity of the bank run in these episodes was generally less than our analysis indicated as tolerable for Norwegian banks given their liquidity reserves.

The new model for liquidity stress testing and the 2024 stress test with a cyber scenario takes us one step further in shedding light on banks' liquidity risk and systemic cyber risk, but there is considerable potential for further development. In the future, the model can be improved in many ways, for example by using different model techniques and by increasing the data collection. This can help improve our analyses of liquidity risk and Norges Bank’s efforts to promote financial stability.

Appendix: 2024 stress test assumptions excluding customer deposits

Money market

It is assumed that banks will mainly lose access to short-term funding in the money market.

In the scenario, uncertainty in the interbank market means that other banks will not place deposits with affected banks and that deposits will be withdrawn. We therefore assume that interbank loans are not rolled over, but that banks in the stress test receive full repayment.

We assume that banks will not be able to refinance in the market for repurchase agreements (repos). This means that banks must repay the entirety of the loan at maturity (cash outflow). At the same time, security pledged as collateral is returned. This will appear as an increase in their liquidity reserves.

We also assume that the counterparty pays back the full amount in repo loans/investments (cash inflow). Liquidity reserves are then reduced correspondingly since the security provided as collateral is returned to the counterparty.

Asset managers and foreign banks are important players in the foreign exchange (FX) swap market. These players are not explicitly included in the model, but the FX market is assumed to function normally, and banks are assumed to have the opportunity to swap for the currency they need. The 2024 stress test does not distinguish between different currencies.

Wholesale funding with long maturities

We assume that the bank loses access to new wholesale funding with long maturities and the ability to refinance as counterparties do not want exposure to distressed banks. Banks must therefore repay wholesale funding at maturity.

Lending

The scenario in the 2024 stress test is not a crisis in the real economy with defaults and losses, but a crisis triggered by operational problems as a result of a cyber attack and subsequent loss of confidence. The default rate therefore does not increase, and customers repay their loans as agreed. This will appear as inflow in the stress test. We also assume that customers will not need to draw on credit facilities.

We assume that the bank does not provide new loans to customers, but that already agreed payments related to mortgages will be paid after one week, when the systems resume operation. However, net lending is reduced as a result of repayments.

Links to covered bond mortgage companies

It is assumed that support from the parent bank to covered bond mortgage companies is not relevant. This is because the scenario is not a crisis in the real economy with defaults and losses, but a crisis triggered by operational problems as a result of a cyber attack and subsequent loss of confidence.

Liquidity reserves

In the model, banks start with liquidity reserves (HQLA) that correspond to the requirement in the Liquidity Coverage Ratio (LCR). The reserves are specified

according to the LCR, ie assets with the highest liquidity and credit quality are classified as Level 1. Subsequently, liquidity and credit quality are assumed to decline in Levels 2A and 2B. Moreover, the model also includes other securities that are not approved in the LCR, but these are not included in the 2024 stress test.

Similar haircut rates as in the LCR are assumed for developments in the value of the liquidity reserves. Banks are assumed to sell securities, so that weighting between the different categories remains unchanged. In the model, no assumptions are made for a specific redistribution of central bank reserves, but the reserves are assumed to be used to cover net outflows in line with other categories in the liquidity reserves.

Banks also have spare covered bond capacity, ie over-collateralisation in covered bond mortgage companies (in addition to legal requirements or requirements from credit rating agencies) or covered bond qualifying loans that have not been transferred from the bank to the covered bond mortgage company. Data for capacity is available in the model, but in the 2024 stress test, we assume that banks do not use this.

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