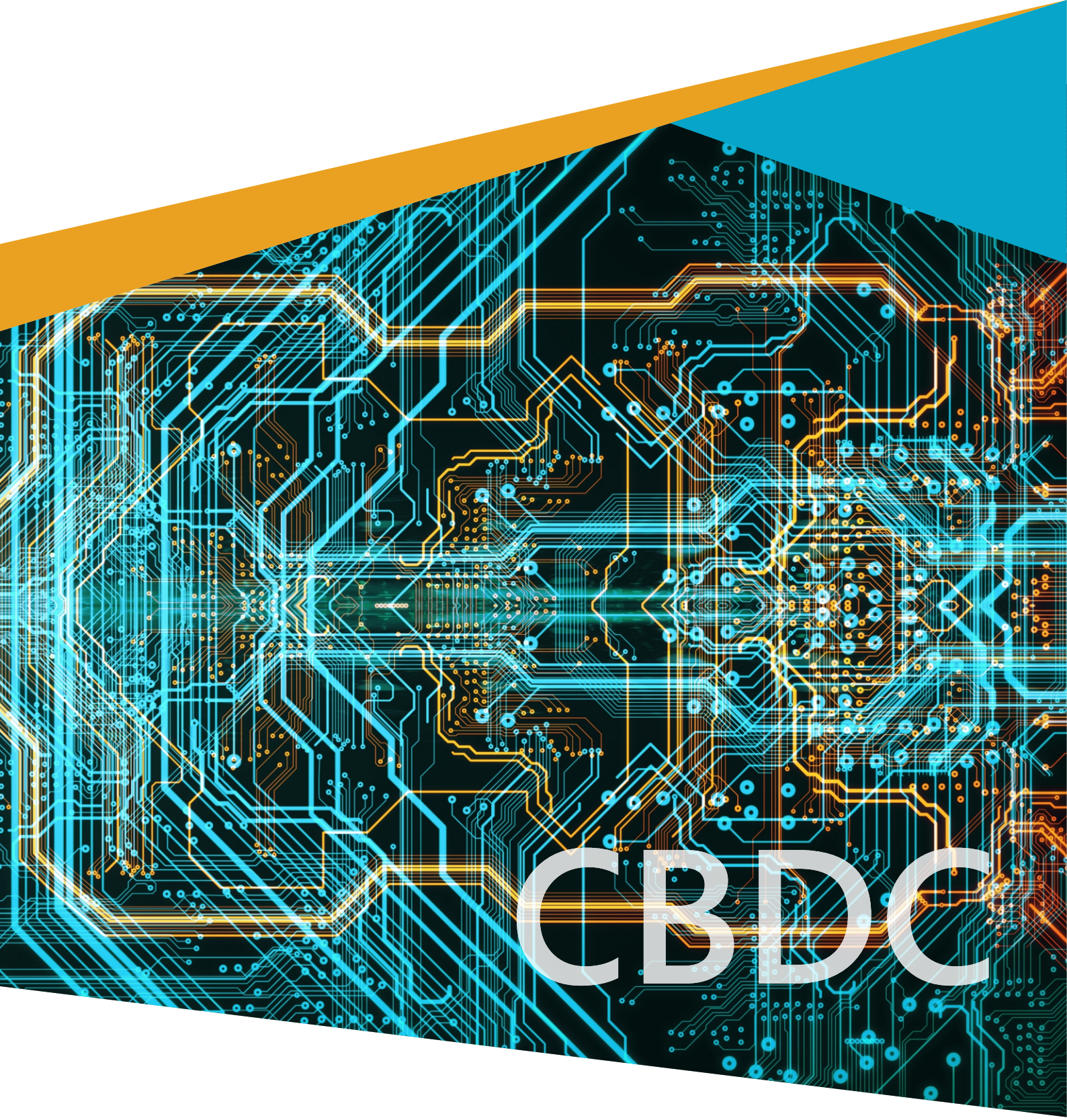

Central bank digital currencies: financial stability implications

September 2021

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in a series of
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group of central banks

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European Central Bank
Bank of Japan
Sveriges Riksbank
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1. Introduction and general overview

In October 2020, this group set out three common foundational principles for considering issuing a central bank digital currency (CBDC) that flow from their common objectives (Group of central banks (2020)). The first of these principles was "do no harm" – this does not mean "have no impact", but rather that new forms of money supplied by the central bank should continue supporting the fulfilment of public policy objectives and should not impede and ideally enhance, a central bank's ability to carry out its mandate for monetary and financial stability. This principle arose from a recognition that while a CBDC has the potential to provide benefits to the operation and resilience of the financial system (particularly regarding payment services), a CBDC could also affect existing financial market structures and business models, which may pose risks to financial stability as the financial system evolves, particularly via the potential disintermediation of banks.

Many jurisdictions are still in the early stages of investigating the case for introducing a CBDC, with key design choices and implementation models still under consideration. For the purposes of this work, we focus on forms of CBDC that are intended primarily for retail use, and that would co-exist with private payment systems. We make an implicit assumption that CBDCs would most likely be offered with tools to minimise criminal usage and money laundering risks ie less anonymous than cash, operating via intermediaries.[1] Many jurisdictions are also actively considering how any CBDC framework might also incorporate safeguards that could reduce uncertainty during any transition, and could also be considered on a permanent basis, eg to have CBDC function primarily as a means of payment rather than as a store of value.

The intention of this report is to consider how, and under what conditions, material risks to financial stability and the ability of authorities to maintain financial stability could arise. The report focuses on the impact on the intermediation capacity and resilience of the banking system, where risks are considered primarily relative to current bank business models and balance sheets. Implications for some aspects of market financing are also discussed. As a result, this initial assessment is bounded by three significant uncertainties: (i) the future structure of the financial system; (ii) the design of a CBDC and its underlying system; and (iii) the size and scale of user adoption.

While this report focuses primarily on potential risks and mitigants, decision-makers will, in practice, need to consider these risks against potential benefits and counterfactuals. For example, similar effects and risks could arise, potentially in a less controllable way, with certain new forms of private sector money. If issued, a CBDC would likely co-exist with private forms of money in a future financial system that could look very different from that which we observe today. Stablecoins are only just starting to be developed and will need to satisfy regulators that they are safe, but subject to that, data-driven business models and strong network effects could mean there is significant use in the future (G7 (2019)).[2] Unlike central banks, issuers of stablecoins are not bound by principles to design products that would co-exist and interoperate with other forms of money or to promote ongoing innovation and efficiency (ie the second and third principles outlined in Group of central banks (2020)). This could cause fragmentation in a payments ecosystem, just like any other closed-loop payment system (CPMI (2018)). Significant stablecoin adoption and the potential consequent fragmentation could result in excessive market power and the type of deposit disintermediation described as a risk for CBDC issuance, but with lower public benefits. As a result, the central banks contributing to this report have already identified that a CBDC could

[1] This includes the possibility that a CBDC could be fully anonymous for small value payments but not for large payments.

[2] Stablecoins vary greatly in risk profile depending on their structure and backing. Hereafter, this report uses the term "stablecoin" to refer to stablecoins that are fully backed by low-risk assets and are well-regulated, so may be perceived as a money substitute.

be an important instrument for ensuring that they can continue delivering their public policy objectives even as the financial system evolves

The report briefly outlines the factors that could affect the take-up of CBDC (also explored in Group of Central Banks (2021b)). Given the considerable uncertainty regarding CBDC demand, a range of take-up scenarios are explored. The report then explores the implications for commercial banks in benign conditions, for non-bank funding, and for the speed and scale of possible bank runs from uninsured deposits. The latter part of the report then analyses options for safeguards and mitigants, although it does not discuss in detail the possible intervention of central banks to use policy tools to offset any transitory impacts on lending.

This report cannot be conclusive and is not a statement of policy. Instead, it adds to previous analysis on this topic by pooling the expertise of central banks who are all actively engaged in similar analysis at a domestic level. By exploring these important dynamics, this report provides a framework for further work as the current financial system evolves and CBDC design options are explored and refined.

Key messages:

- To help maintain safety and stability, a CBDC would need careful design and implementation, allowing time for the existing financial system to adjust and flexibility to use safeguards.
- CBDCs would have implications for financial intermediation and would need careful design and implementation; but our analysis suggests the impacts on bank disintermediation and lending could be manageable for the banking sector. A significant shift from bank deposits into CBDCs (or even into certain new forms of privately issued digital money) could have implications for lending and intermediation by the banking sector. However, our analysis also suggests that these impacts would likely be limited for many plausible levels of CBDC take-up, if the system had the time and flexibility to adjust. This initial assessment is subject to uncertainties over the future structure of the financial system, the design of a CBDC and its underlying system, the size and scale of user adoption of CBDC and differences between jurisdictions.
- We note that the financial system is dynamic and evolving and has successfully navigated episodes of structural change over many years. Additionally, private sector developments may generate similar deposit substitution risks, irrespective of CBDC and the introduction of CBDC may generate additional innovative opportunities for banks and other financial intermediaries. Central banks would have to carefully consider how they would manage these impacts, particularly through any transition phase for CBDC.
- However additional risks to financial stability might arise if changes in the structure of the financial system due to the adoption of a CBDC were to be abrupt. Impacts would also depend on the extent of the offsetting increase in lending to the real economy by non-bank financial intermediaries. CBDC and certain new forms of digital money could also increase the latent risk of systemic bank runs. This risk is reduced in the existing system through effective banking regulation, deposit insurance, and resolution frameworks
- Central banks are exploring safeguards that could be built into any CBDC to address financial stability risks; although such measures may need careful consideration before they were used. Central banks might consider measures to influence or control CBDC adoption or use. This could include measures such as access criteria for permitted users, limits on individuals' CBDC holdings or transactions, and particular choices around CBDC remuneration. Such measures could be valuable in managing risks in any transition were a CBDC to be introduced and could potentially have a role on a longer-term basis in some jurisdictions. However, such measures would also bring challenges. The design of any measures would likely need to balance moderating the risks from high and/or rapid take up of CBDC with other policy objectives associated with a meaningful level of usage. In some cases, there could be legal and public policy issues to consider. For

example, there might be some measures that may face obstacles to public understanding and acceptance.

- Further work is needed to fully understand the entire range of effects and quantify the possible implications for financial stability from CBDCs, particularly to understand potential take-up for different CBDC designs, the optimal design of any safeguards, how non-banks and third-party providers might be affected, and the opportunities to enhance financial stability as the payments landscape continues to evolve. Observations from early CBDC launches and pilot schemes could be very useful in this regard.

2. CBDC take-up potential and bank deposit substitution

Money and payments are changing fast. The Covid-19 pandemic has accelerated a number of recent digital payment trends across advanced economies. Growth in e-commerce has expanded online payments and in-person transactions increasingly use contactless debit and credit cards. Before the pandemic, although cash circulation was growing, its use for payments had been declining in most countries and the number of ATMs falling (Boar and Szemere (2020)). At the end of 2019, cash holdings per capita ranged from around $500 to $7,000 across the jurisdictions covered by this group of central banks, while bank deposits per capita varied from $20,000 -$100,000 (Graph 1) – without a strong correlation apparent between the relative levels of the two variables across these jurisdictions. Pandemic lockdowns have apparently amplified earlier trends, by driving a decline in withdrawals and fewer opportunities to use cash, resulting in access concerns in some jurisdictions (Auer et al (2020)). In this context, more central banks than ever are investigating general purpose CBDCs (Boar and Wehrli (2020)).

Potential demand for a CBDC is highly uncertain. It would be affected by its design and implementation framework (Group of central banks (2021a and 2021b)). For example, demand would likely depend on the importance to individual users of the following factors relative to available alternatives at the time such as cash, bank deposits, e-money and other tokens:[3]

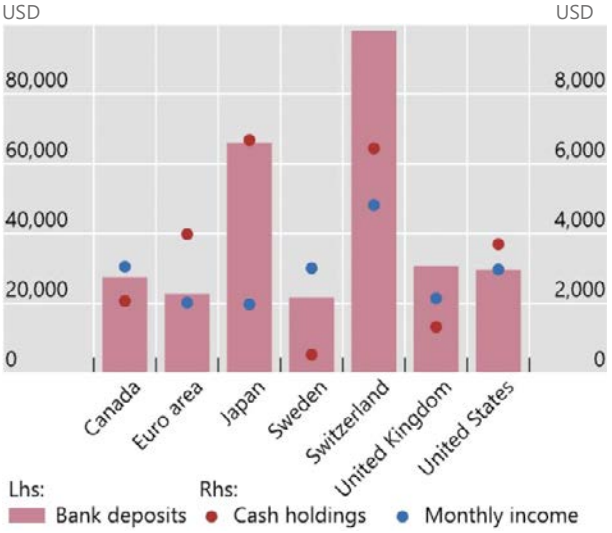
- Perceived safety versus insured or uninsured alternatives;
- Ease of access/financial inclusion;
- Interoperability with and speed of alternative means of payment;
- Technological innovation, eg programmability;
- Remuneration;
- Cost of use;
- Privacy and anonymity; and
- Ease of switching between CBDC and alternatives.

In the jurisdictions represented by this group of central banks, no decision regarding whether or not to issue a CBDC has been made and discussions are still underway regarding design choices (Group of central banks (2021a)). If jurisdictions decide to issue a CBDC, in most cases the actual introduction of CBDC could be some years away. In the interim providers of private money and tokens are expected to continuing developing and expanding their service offerings.

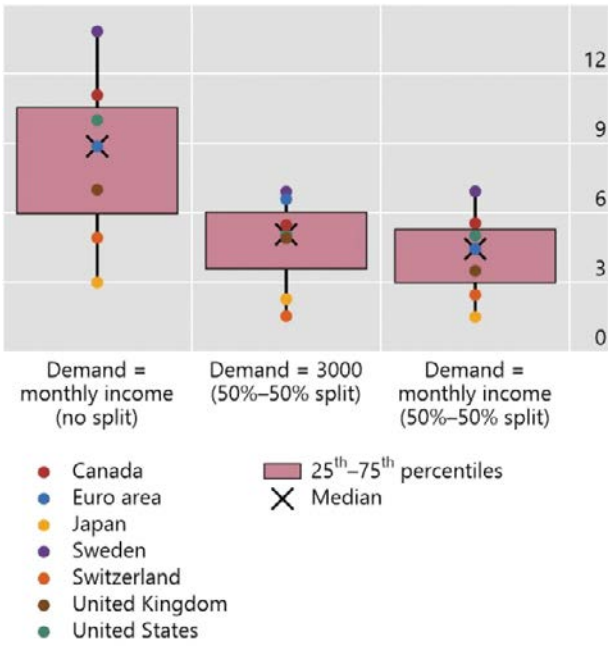
[3] Khiaonarong and Humphrey (2019) also find that demand will depend on the extent to which cash has already been substituted with other means of payment, such as bank debit cards, as without further incentives CBDC would not provide extra convenience over a bank debit card. However, in jurisdiction in which cash use is very high, demand for CBDC should be stronger due to a lack of cash substitutes already in place.

Household sector balance sheets and incomes could be one influence on CBDC adoption Graph 1

Bank deposits, disposable income and cash holdings per capita[1]



Illustrative scenarios for potential household CBDC adoption and deposit substitution[2] Percentage of bank deposits



[1] Bank deposits and cash holdings represent respectively deposit assets per capita and currency holdings of households and non-profit institutions serving households (NPISH) using 2018 OECD financial balance sheets data. Monthly income represents median disposable income of total population based on 2018 OECD Income distribution database. For the conversions of median disposable income from local currencies to USD, the USD exchange rate of 31 December 2020 is used. Per capita calculations use United Nations' World population prospects 2019 data and are based on total population. [2] "Demand" illustrations indication of CBDC take up relative to bank funding for heavily implied and stylised scenarios using 2019 data where demand is equivalent to: (i) monthly income, all substituted from bank deposits; (ii) demand per households USD 3,000 with substitution split equally between cash and deposits; and (iii) demand is equivalent to monthly income with substitution split equally between cash and deposits.

Sources: OECD financial balance sheets, non-consolidated - SNA2008, OECD income distribution database, OECD GDP database. UN World population prospects 2019. Data for euro area from ECB Statistics bulletin.

There could be material demand for an unremunerated or uncompetitively remunerated CBDC, if its other features such as cost, safety, ease of access etc are deemed to be valuable by users. If a CBDC were intended as a means of payment, rather than a form of investment, then it could pay an uncompetitive interest rate, negative interest (for example, to avoid undercutting bank deposits in jurisdictions where interest rates are negative) or be left unremunerated. Demand for existing non-interest-bearing electronic money such as "e-money" in the UK and EU has been relatively low. However, CBDCs would be as safe as cash, with added electronic benefits and possibly attracting greater demand.

A remunerated CBDC would be an even more attractive substitute for cash, low interest-bearing deposits or other cash-substitutes. According to Li (2021), remuneration is one of the most important attributes that affects the potential demand for CBDC. The magnitude of the demand would still though depend on a range of factors, including safeguards (discussed in Section 5), and convenience factors such as the ease of use via digital wallets. It could be attractive to households that are particularly risk-averse or have already spread deposits across multiple bank accounts to minimise balances above deposit protection limits. Businesses might also wish to transfer some of their uninsured balances to a CBDC.

That said, demand inertia might limit or slow sizable shifts to any CBDC, unless it were very competitively remunerated and/or offering better functionality. Some studies have shown that demand

for deposits is relatively insensitive to interest rate differentials between banks, due to demand inertia.[4] But CBDCs would be a new asset and the cost to users of setting up a new relationship could be very small.[5] Therefore, the elasticity of demand for CBDC might be somewhat greater if perceived barriers to transferring money to it are lower.

Studies to date that attempt to estimate CBDC take-up find very wide ranges, reflecting the large uncertainty around CBDC adoption, and find high sensitivity to CBDC features. Li (2021) uses Canadian household survey data to quantify the expected demand of CBDC by households and estimates that households could hold from 4% to 55% of their combined cash and deposit holdings in CBDC depending on the features of the CBDC. In particular, the lower estimates would apply if the CBDC had more cash-like features, while the higher estimates would likely reflect a CBDC designed with characteristics that made it competitive with bank deposits. Bank of England (2021) considers an illustrative scenario in which about 20% of household and corporate deposits migrate to CBDC owing largely to non-financial factors such as safety and convenience. A simple exercise replicating the analysis of Bindseil (2020) for G20 economies where data is available, which assumes that CBDC take-up is driven by monthly incomes of people over 14 years old, and three macroeconomic metrics (income distribution, population size, and banks' share of funding from households), suggests that the domestic demand for CBDC could range between 4% and 12% of bank funding, although these figures would be lower if part of the demand reflected substitution from cash (Graph 1).

In time, data from early CBDCs should provide insight on their take-up. Until then, analysis of CBDCs' implications should consider a range of potential take up scenarios given the significant uncertainties. In the coming year, data should start to become available on the rollout of some early CBDCs, notably the Bahamian "sand dollar" launched in October 2020 and the digital Yuan currently in pilot testing. In particular, the sand dollar also has a notable two-tier system that should provide insight on the importance of some non-pecuniary factors. There are two tiers of sand dollar account, both of which are unremunerated, but "Tier 1" accounts have lighter identification requirements, cannot be linked to bank accounts and so have lower holding limits and lower monthly transaction limits than Tier 2 accounts.[6] Authorities could also consider launching consumer attitude or other market research surveys to follow public awareness of CBDCs, their features and interest in take up across the population.

[4] For example, Chiu and Hill (2015) estimates that a 1% increase in the bank deposit rate was associated with an increase in the stock of deposits of around 0.3% over 12 months.

[5] In principle, users could hold a CBDC without a bank account (through a digital wallet). Hence the cost of setting up a new would likely be lower and the elasticity of demand higher.

[6] https://www.sanddollar.bs/individual

3. Implications for bank funding, lending and resilience

The potential for the introduction of a CBDC to affect financial stability risks arises primarily from a significant substitution away from private money, while central bank cash-to-CBDC substitution is generally regarded as having no implication for financial stability[7]. Even as the financial system is evolving rapidly, private banks are in all jurisdictions still the dominant source of private money. The money creation process is intrinsically intertwined with bank credit provision, which in turn supports a banking system providing a wide range of intermediation and payment services. As a result, the analysis that follows focuses on the implications of CBDC substitution for bank deposits (and later other money instruments).

Absent limits to individual holdings, a CBDC (like other forms of digital money) could lead to higher volatility in deposits and/or a significant, long-term reduction in customer deposits. This could, under certain circumstances, affect bank profitability, lending and the overall provision of financial services. Customer deposit funding is at the heart of the commercial banking business of maturity transformation and intermediation services. Away from issues of the zero-lower bound, any material loss in customer deposit funding would require banks to consider combinations of actions to try and maintain regulatory ratios and risk-adjusted profitability, eg:

- Switching to alternative market-based funding sources which could be more expensive and, in some cases, less stable;[8]
- Reduction in assets/deleveraging;
- Increased risk taking to mitigate near-term margin compression;
- Increased lending rates;
- Actions to offset any lost fees and commissions on activities associated with customer deposits, eg ancillary payment services. These could include actions that improve competition for customer deposits or leverage a role as CBDC intermediary.
- Cost efficiencies (eg lower cost of cash handling).

There is a small but growing set of literature seeking to consider the magnitude of these challenges, and their implications on bank lending (availability, cost and economic impact; Box 1). While there are studies suggesting both positive and negative overall effects of a CBDC on aggregate lending and economic activity, a common theme is that maintaining bank profitability levels could be challenging, and that the magnitude of the implications will depend on the exact design of the CBDC. Assumptions regarding the substitutability between deposits and CBDC, the level of competition in the banking sector, the functioning of the market for loans from non-banks, and the new role of the central bank are crucial determinants of the structural implications of CBDC.

A stylised model of an aggregate banking system can shed light on how material some of these challenges may be in typical, benign conditions, for a range of hypothetical CBDC take-up scenarios (assuming an environment with positive interest rates). Taking some high-level features of an aggregated banking system balance-sheet, combined with some simplified assumptions on how that system may respond to a loss of customer deposit funding, can provide a guide to the scale of knock-on effects for funding costs, effective lending rates and bank profitability (see Annex A for details of the model).

Specifically, we can consider one case where the banking system seeks to offset all CBDC capture of customer deposits via long-term wholesale funding – a costlier alternative to customer deposits. In this case, following deposit outflows, banks seek to maintain their lending volumes and leave their regulatory

[7] Substitution away from cash towards CBDC may ultimately affect the economic value of continuing to issue cash, although most jurisdictions have committed to ongoing cash production for the foreseeable future.

[8] In the short term, banks may also be able to turn to central bank funding, subject to central banks' willingness to lend.

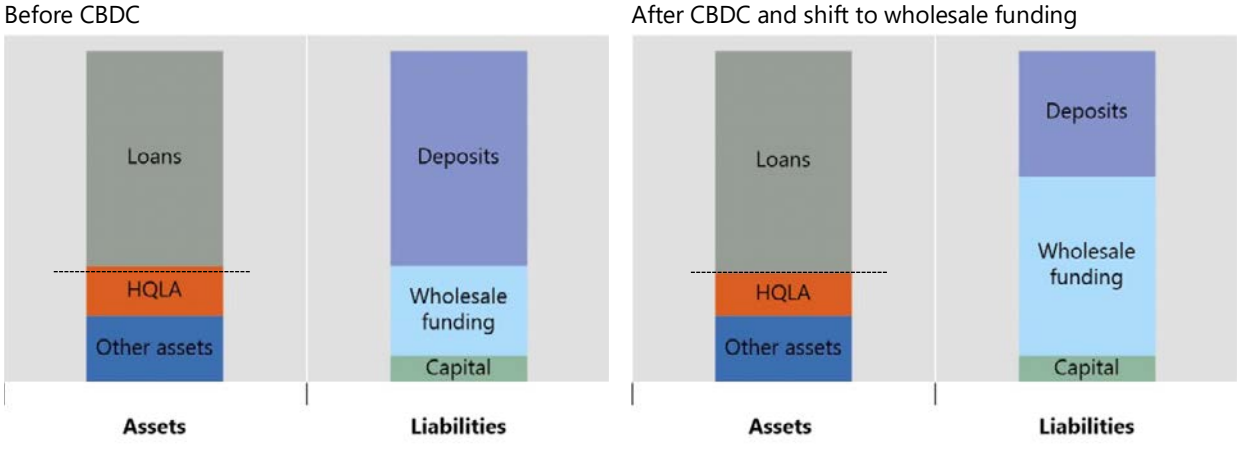
liquidity ratios unchanged.[9] They do this by issuing long-term wholesale debt to buy enough high-quality liquid assets (HQLA). Under current regulatory design, banks do not need to replace all their lost deposits with wholesale funding because long-term wholesale funding requires less HQLA to be held against it than deposits (Graph 2). For simplicity, long-term wholesale funding rates, non-interest income and non-funding expenses are assumed to remain unchanged. Banks' weighted average funding costs increase due to the substitution of deposits with relatively more expensive wholesale funding. Therefore, for a range of CBDC take-up scenarios, we estimate how much this response increases banks' weighted average funding costs and reduces net interest margins (NIMs) and return on equity (RoE), other things held constant. Finally, banks may seek to offset that impact on their profitability by raising lending rates, which for simplicity is assumed not to trigger reduction in lending volumes.[10] We estimate by how much banks would need to increase lending rates to maintain profitability.

The model itself does not depend on the level of the central bank policy rate because results are a function of the degree of deposit outflow and the spread between wholesale funding and deposit rates.

The introduction of a CBDC could weigh on banks' profitability if banks kept lending (at unchanged interest rates), for a wide range of take-up scenarios (Graph 3, left-hand panel). The model estimates that wider spreads between deposit and wholesale funding rates, coupled with sizeable deposits outflows, translate into a larger profitability loss.[11] If banks were to maintain their profitability, they may seek to increase the interest rates on loans (Graph 3, right-hand panel). Both graphs are shown under different illustrative spreads between wholesale funding and deposit rates (0.5 to 2% pts). As an illustrative guide, a line showing the average wholesale funding-deposit spread for advanced countries from 2017 to 2021 of 0.63% pts is included in the graphs.[12] The stressed outflow factor in the liquidity coverage ratio (LCR) and the initial LCR are assumed to be 15% and 125% respectively, representing a range including retail deposits and business operational deposits.

Illustration of aggregate banking system balance sheet before and after CBDC introduction, assuming replacement with long-term wholesale funding

Graph 2



Source: Working group

[9] Focusing on the liquidity coverage ratio (LCR).

[10] This is a partial equilibrium exercise, ie banks can adjust their rates without changing quantities.

[11] To give a sense of the magnitude of RoE measured as a simple average across the euro area, "other Europe", the United States and "other advanced and emerging markets", the RoE was 7.5% and 8.9% (on average) in 2016 and 2000-2016, respectively. Data source: CGFS dataset.

[12] This spread is indicative of relatively benign conditions and is in part a function of the low interest rate environment and strengthened bank resilience since the global financial crisis. The spread widened during the global financial crisis (ie stress conditions) to a high of around 3% pts.

Box 1

CBDC impact on lending and economic activity - insights from research

Although still relatively small, the emerging literature on the potential impact of CBDCs on banking systems already offers a wide range of argumentation with some areas of consensus. This box draws together the high-level findings from a range of studies that focus on how a CBDC affects issues relevant to financial stability, primarily through impacts on bank deposit funding, competition, risk-taking/market discipline and susceptibility to bank runs.

Researchers are not unanimous on the potential impact of a CBDC on bank deposit funding but many note impacts on competition. A sizeable body of literature (CPMI-MC (2018), Fernandez-Villaverde et al (2020), Keister and Sanches (2019)) stipulates that a CBDC would structurally decrease deposit funding available to commercial banks as a CBDC, being on a par with deposits with regard to liquidity and convenience, would also offer advantages as a safe haven asset. That said, Chiu et al (2019) and Kumhof and Noone (2018) argue that in an imperfectly competitive deposit market, the existence of CBDC as an outside option forces banks to match the CBDC rate to retain their deposits, which would eventually have a crowd-in effect of encouraging saving. Andolfatto (2018) argues that the introduction of interest-bearing CBDC will increase financial inclusion in systems in which the banking sector is not perfectly competitive while simultaneously diminishing demand for cash.

Many studies argue that CBDC is likely to weigh on bank profitability and lending. If banks respond to a CBDC by increasing reliance on market funding, then depending on the type of market funding (ie wholesale deposits, long-term debt, longer-term money market instruments), banks' maturity transformation and their liquidity risk may face upward pressure because of more reliance on less stable funding sources, or some downward pressure if market discipline increases (Mancini-Griffoli et al (2018)). They say that the volatility of market-based funding may increase the pro-cyclicality of bank lending.

Competition from CBDCs may also prompt banks to increase deposit rates. In Keister and Sanches (2019), higher deposit rates lead to lower lending as some projects that are profitable at a lower cost of funding fail to secure cost-efficient bank financing. Agur et al (2019) and Mancini-Griffoli et al (2018) note that when banks have sufficient market power, they may try to compensate for higher deposit rates by increasing the interest rates charged on lending, lowering the demand for loans. Piazzesi and Schneider (2020) argue that the introduction of a CBDC by the central bank could cause a reduction in commercial bank deposits which would consequently translate into more expensive credit lines. The authors suggest a decline in welfare if the benefits of the CBDC are outweighed by higher credit line costs. The analysis is based on several strict assumptions such as that CBDC is seen only as a deposit substitute (and not as cash alternative) and that banks main function is liquidity provision.

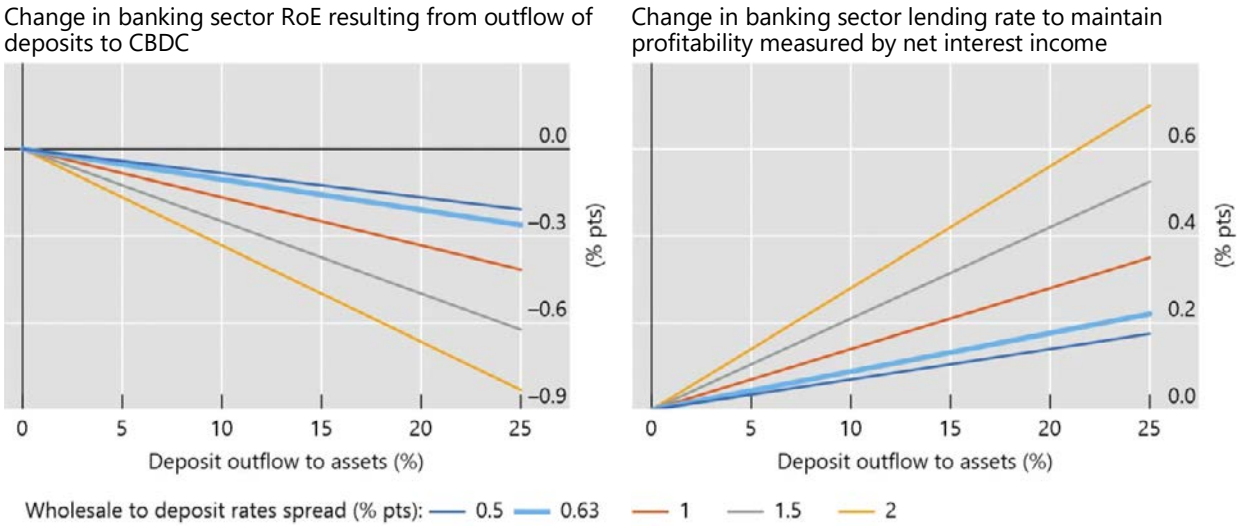
Some studies note the potential for increased competition created by a CBDC to increase the overall depositor base, in turn expanding lending and/or reducing borrowing costs. Andolfatto (2021) argues that higher deposit rates could increase the deposit base, and lower borrowing rates thus expanding banks' lending. Similarly, Chiu et al (2019) conclude that under imperfect bank competition in the deposit market, higher deposit rates can increase lending by increasing deposit demand. They argue that, even when CBDC is not used in equilibrium, its introduction provides a lower bound on deposit rates, limiting monopoly profits of banks in the deposit market and inducing them to lend more.

Another set of studies focus on the risk that a CBDC may increase depositors' sensitivity to system-wide banking crises by facilitating the transfer of deposits. The availability of CBDC might not have a large impact on individual bank runs as it is already possible to digitally and instantly transfer money between a weak and a strong bank (Kumhof and Noone (2018) and Carstens (2019)). However, during a systemic banking crisis, transfers from bank deposits into CBDC would face lower transaction costs than those associated with cash withdrawals (such as going to the ATM, waiting in line, etc.), and would provide a safe-haven destination in the form of the central bank. The lower costs of running to CBDC compared to cash imply that more depositors would quickly withdraw at a lower perceived probability of a system-wide bank solvency crisis (Broadbent (2016) and Callesen (2017)). Yet, the impact of a CBDC on the speed, scale and frequency of systemic bank runs depends crucially on its design, and on the credibility of deposit insurance (Mancini-Griffoli et al (2018)).

The scenarios just described are subject to risks in either direction. On the one hand, non-linearities and general equilibrium effects, not included in the modelling, could imply more costly outcomes. For example, the cost of wholesale market funding may increase given increased demand for it and as investors may seek increased compensation for risk if their own portfolios rotate from HQLA (likely government bonds) towards bank debt. On the other hand, any increased demand for government bonds by banks may push down government bond yields. Banks' long-term wholesale funding cost is made up of the long-term risk-free rate plus a credit spread. Any fall in long-term risk-free rates from banks buying government bonds would help mitigate any increase in banks' wholesale debt funding costs.

Illustrative exercises estimate the potential for impacts on bank profitability and lending if CBDC prompts an outflow in customer deposits[1]

Graph 3



[1] See Annex A for details on data sources and model parameters.

Source: Country Banking Data Tables from CGFS publication No. 60, BIS bank level asset data and BIS bank level deposit and CDS rates. Data is obtained for a subset of advanced economies.

At the same time, if a CBDC led to lower cash usage, banks may also be able to reduce the costs associated with cash handling, helping their overall profitability. Cash operations have been estimated to account for between 5% and 10% of total bank operating costs (McKinsey (2018)), suggesting the potential for significant cost savings from lower cash handling. Actual cost savings would likely be lower, however, as many jurisdictions have indicated that even if they introduce a CBDC, they intend to maintain physical cash for the foreseeable future; in addition, many jurisdictions have policy goals to maintain widespread access to cash and cash distribution across their country. Table 2 sets out some of the key factors that could lead to a higher or lower change in lending rates than in the modelled scenario.

Overall, this analysis suggests that a CBDC could impose some costs via different channels, such as lower bank profitability (and in turn, bank resilience), higher bank lending rates or reduced lending - although this work does not consider how these costs compare to the potential welfare benefits of a CBDC. Moreover, similar effects could emerge in case of a large take up of new forms of private money, such as stablecoins.

In any new steady state with meaningful take-up of CBDC or other digital forms of money, banks may have to react to a smaller deposit base. If banks choose to cut lending in order to repair their liquidity positions, they would destroy a deposit somewhere else in the banking system, propagating the liquidity problem to another bank. So, banks must in aggregate opt for alternative funding sources, such as

issuance of long-term debt.[13] This means that their funding costs would increase. It could also mean that loan prices may become more sensitive to market conditions. While central banks can in principle also be a source of alternative funding, such funding – whether temporary or structural - may need to be provided against lower quality collateral as only that would increase HQLA for banks. The long-term implications of any structural central bank funding as well as the monetary subsidy of funding would need to be carefully considered further. In addition, the quest for different funding sources may result in an increased reliance on non-bank sector, raising the need for regulatory supervision and possibly creating regulatory perimeter issues.

A CBDC could also pose greater challenges for some business-models or parts of the banking sector. Large banks with relatively higher share of (non-interest or low interest bearing) transactional deposits may be more likely to lose deposits to the CBDC than banks with higher-rate savings deposits (eg building societies). Conversely, those large banks may have better access to wholesale debt markets than smaller banks, enabling purchases of HQLA. Some small banks with a business model focused on payments may be particularly vulnerable to the introduction of a CBDC.

Sensitivities of lending rates to assumptions Table 2

	Upward pressure on the change in lending rates	Downward pressure on the change in lending rates
The cost of long-term wholesale debt, and banks' weighted average marginal funding cost	Cost might rise as banks increase debt issuance if investors want additional compensation to shift their portfolios from government bonds to bank debt. Bank debt is often bought by institutional investors in international markets. So the impact on lending rates could also depend on international cross-currency swap markets.	Cost might fall if banks' higher demand for government bonds (HQLA) resulted in lowering government bond yields. In that case, the risk-free rate component of wholesale funding costs could fall. However, a fall in government bond yields would also reduce the return banks earned on their HQLA portfolios and so offset the benefit on the funding side.
Deposit rates	Could increase if banks bid up deposit rates to slow non-pecuniary deposit outflows or if the interest rate on a CBDC is attractive.	
Non-interest income	Banks could seek to increase lending rates if they lose non-interest income associated with deposit activity. Alternatively, they might charge more fees or seek other business activity.	Banks could seek to reduce lending rates if they lose non-interest income associated with lending activity.
Banks' marginal funding rate used to price lending may not include deposit costs		Banks may price lending based on long-term wholesale funding costs alone. In that case, the impact on lending rates from CBDC would depend on the extent to which increased long-term wholesale issuance drove up long-term wholesale funding rates. In this case, the shift from deposit to wholesale funding may have less impact on banks' loan pricing.
Competition for lending		An increase in loan rates might be mitigated by competition from non-bank lenders and capital markets. However, this effect could be stronger for some forms of lending (eg large corporates) than for others (eg SMEs).

[13] Banks could also issue shorter-term wholesale debt to replace lost deposits but could face greater subsequent hurdles meeting regulatory liquidity requirements (eg the LCR).

At the same time, introduction of a CBDC has the potential to offer new opportunities for innovation, which may benefit banks, and non-bank/third-party providers of financial services, supporting a competitive and diverse financial system. Depending on its functionality and level of interoperability, the introduction of a CBDC could enable banks and other intermediaries to offer innovative payment services to their customers (such as programmable payments). Or it could allow for more diverse forms of finance, with less need to rely on centralised payment intermediation, eg less reliance on correspondent banks in international payments. This could facilitate new opportunities for innovation and increase the resilience of the system overall – subject to authorities ensuring appropriate regulation of all parties. In parallel, greater competition for deposits, and possibly also for lending, could also bring in new entrants or encourage expansion of lending by non-banks. Again, more diversified sources of finance would tend to increase the resilience of the financial system overall, subject to robust prudential frameworks.

It is also possible that non-banks would extend credit to replace some bank lending directly, if they chose to adjust their own portfolio composition – although this may in turn affect non-banks' provision of other financing, including to banks. Many advanced economies operate with relatively high levels of non-bank finance with correspondingly smaller shares of household assets held as deposits with the banking system. While it provides more diverse forms of finance, non-bank finance is unlikely to be a perfect substitute for bank finance, especially for lending to some smaller companies. That is because this lending often requires the lender to have specialist information. This is currently an area in which commercial banks have an advantage given the information to which they have access on their customers' deposits.

CBDC could partially replace banknotes in circulation, which would result in a swap between these two liabilities on the central bank's balance sheet. CBDC could also substitute a share of customer deposits at commercial banks, resulting – in the first instance – in a swap between CBDC and reserves on the liabilities side of the central bank's balance sheet, if banks have enough central bank reserves. The latter case would probably have a more significant impact on the aggregate balance sheets of various sectors in the economy, in particular the commercial banking sector.

In a scenario where CBDC leads to a significant decline in deposits at commercial banks and reduced the level of aggregate reserves in the system sufficiently to exert pressure on key short-term money market rates, the central bank could adjust the supply of reserves to stabilise rate pressures. It would have two main options to do so – either through asset purchases or lending operations – both of which would increase the size of the central bank balance sheet relative to the pre-CBDC case. Increasing reserves through asset purchases could not only impact those asset markets in which the central bank was making purchases, such as government securities, but also enlarge the central bank's footprint in these markets.

Once any transition to a CBDC had occurred, central banks would need to consider the size and volatility of the aggregate CBDC liabilities on the central bank balance sheet in steady-state. If the aggregate CBDC liability proved large and volatile, it could be more difficult for a central bank to forecast components of its balance sheet, with potential consequences for the size and frequency of central bank operations in money markets. Flows into and out of CBDC that are not matched by corresponding shifts in the demand for banknotes would affect the amount of reserves in the system, in the way that changes in the stock of banknotes or central bank deposits held by non-monetary institutions (eg the finance ministry, foreign central banks, or financial market infrastructures) currently do.

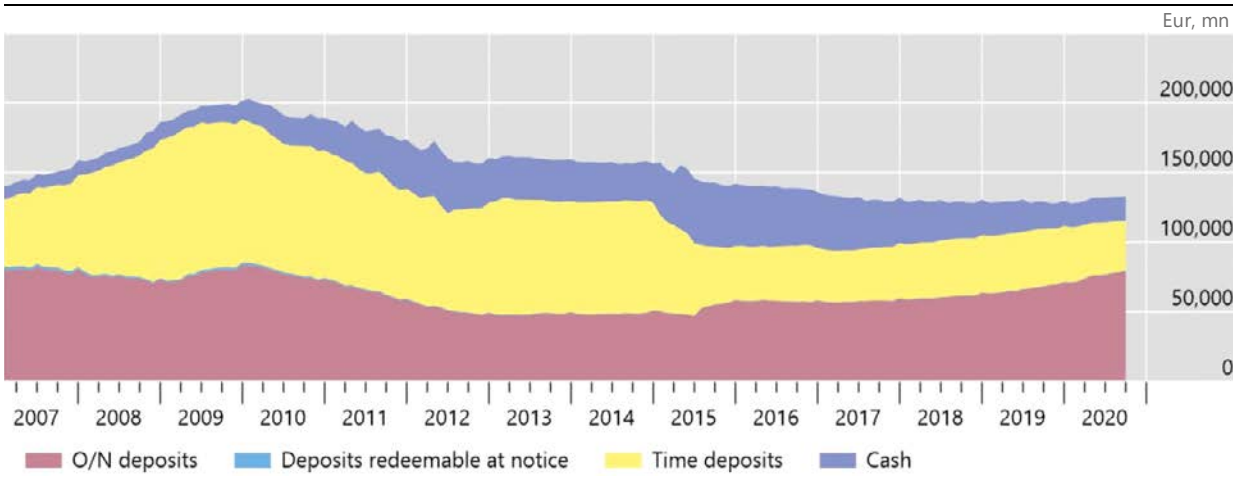
4. Possible effects on systemic bank runs or abrupt money-market withdrawals

In addition to the potential impact of CBDC in benign conditions, during crisis periods a CBDC could be perceived as a safe haven making bank deposits, particularly uninsured deposits, more flighty and thus increasing the risk of bank runs (see Box 1 for literature). Online cash transfer services, digital currencies and fast payments services have already increased the ease of withdrawing deposits in recent decades. At the same time, stronger prudential regulation of banks and reinforced deposit insurance schemes in many countries since the financial crisis have reduced incentives for retail and wholesale customers to run on banks. Nonetheless, the introduction of a CBDC (or certain new forms of private money) might increase this risk in stress by providing an easily accessible recourse to a safe asset - although the specific mechanics of any run would be impacted by the legal and operational design of the CBDC and its handling by banks or other financial service providers. For example, there may be distinct dynamics related to a CBDC that is held/serviced by financial institutions for their customers. Moreover, limits on individual holdings or withdrawals could be introduced by authorities or intermediaries to manage the risk of sudden deposit outflows (see Section 5).

Evidence from previous systemic bank runs indicate how powerful the impetus of a bank run is, and therefore how the reduced transaction costs of a CBDC could exacerbate bank runs. For example, when the Japanese financial crisis erupted in the late 1990s, it took a week or so for the deposits of failed banks to fall by 10% (Table 3). The central bank and regulatory body thus had some time to plan and provide ex-post interventions, including any changes to deposit insurance and lender of last resort, to tackle the crisis. As for the bank runs that happened amid concerns over "Grexit", the deposits of Greek banks fell in total by just over 30% and about 25% respectively from 2010-2012 and 2014-2016 (Graph 4). If funds could have been shifted into a CBDC, the damage to the Greek banking system could have been greater still.

The Greek banking system household sector deposit and cash outflows

Household sector deposit and cash profile of Greek banks — Graph 4



Note: Outstanding amount of bank deposits of households and non-profit institutions serving households (NPISH) reported by Greek monetary financial institutions. Cash represents currency holdings reported by Greek households and NPISH.

Source: ECB Monetary financial institutions balance sheet items. ESA2010 quarterly financial and non-financial sector accounts.

Beyond banks, it is possible that CBDCs could be a substitute for investments in other low risk, liquid assets, such as Money Market Funds (MMFs) and Treasury Bills, leading to abrupt shifts in their funding. There are a subset of non-bank intermediaries and capital instruments that have some asset features (and in some cases, payment features) that are close to bank customer deposits and cash. For example, at end-2019, there were an estimated $7trn of assets under management in money market funds (Avalos and Xia (2021)). Depending on its design features and relative remuneration, introduction of a CBDC could be an attractive alternative for some risk-averse holders of other cash substitutes, even in benign conditions. This in turn could reduce the demand for assets that such funds invest in, possibly affecting yields in turn. That said, in benign conditions demand to move into CBDC could be limited if many investors, including institutional or retail investors, also have some appetite for risk by nature. The extent of this demand is also likely to be contained if CBDC is restricted to retail use.

Outflows of deposits from banks during the 1990s Japanese banking crisis

In yen, billion Table 3

Bank	Day of announcement	Deposits outstanding on final business day	Outflow of deposits (accumulated)		
			First day	First week	First month
Hokkaido Takushoku Bank	17 Nov 1997	5,603	210 (4%)	856 (15%)	1,571 (28%)
Tokuyo City Bank	26 Nov 1997	576	40 (7%)	110 (19%)	173 (30%)
Kokumin Bank	11 Apr 1999	538	44 (8%)	123 (23%)	173 (32%)
Kofuku Bank	22 May 1999	1,689	59 (3%)	191 (11%)	273 (16%)
Tokyo Sowa Bank	12 Jun 1999	1,994	60 (3%)	232 (12%)	466 (23%)
Namihaya Bank	7 Aug 1999	1,457	40 (3%)	102 (7%)	196 (13%)
Niigata Chuo Bank	2 Oct 1999	918	32 (3%)	84 (9%)	152 (17%)

Source: Nakaso (2001)

Large-scale MMF outflows in the global financial crisis (GFC) and at the onset of the Covid-19 pandemic also indicate that a CBDC could increase the risks of "runs" from non-banks in stressed conditions. This risk is greatest for non-banks reliant on short-term funding. The onset of the GFC saw a very large shift out from prime MMFs in the US, which had negative effects on other short-term markets. Although the financial reforms after the crisis resulted in a reallocation of funds from prime MMFs to government MMFs, prime MMFs faced large swings in inflows and outflows in the initial months of the Covid-19 pandemic, reflecting periods of investors withdrawing balances in a "dash for cash" and also investors turning to MMFs as a safe-haven in other periods (Eren et al (2020)). The critical question is whether and how the introduction of a CBDC would affect the run dynamics in prime MMFs by offering an alternative safe haven other than reallocating funds to government MMFs. CBDC remuneration and the ability to redeem MMF shares directly into CBDC without going through the payment system are important considerations. Contrary to institutional MMFs, retail prime MMFs in the US did not experience large

outflows during the Covid-19 pandemic. As discussed above, concerns about elevated run risk in MMFs would be mitigated if CBDC were restricted to retail use.

In addition, a structural shift away from transactions in some money markets could affect the robustness of critical interest rate indices. Money market transactions specifically overnight unsecured deposit transactions, in which MMFs are key participants, are also used to determine interest rate benchmarks, such as SONIA or EONIA. As was seen in the past with LIBOR, the integrity of indices, which matter for financial market functioning, requires sufficient transaction volumes in the underlying markets.

5. Options for safeguards

The previous sections have described how a large shift from bank deposits to CBDC has the potential to affect current banking sector business models, possibly in a disruptive way, reducing the availability or increasing the cost of lending and even increasing the risk of systemic runs. Disruptions may occur in any case and be less easily controlled with the introduction of new forms of private money such as stablecoins and could also involve other parts of the financial system. But whether these challenges would indeed be disruptive would depend on the scale of the take-up of CBDC (or private digital money), how quickly any substitution occurs and extent of offset from third-party and non-bank financial service providers.

CBDC design or its framework can help control the risks to financial stability, including by mitigating risks that could arise with new forms of private money as noted in Section 1. Depending on the specific rationale in a jurisdiction for pursuing CBDC, the functionality of the CBDC or the payment infrastructure and entities that support it could be tailored to fulfil that rationale while mitigating side-effects. Any safeguards aimed at moderating take-up must also be balanced with allowing a CBDC to fulfil its policy objectives, and some safeguards may be easier to implement than others.

5.1 Measures to moderate CBDC take-up and limit substitution

Moderating CBDC take-up would be the most direct route to mitigate the identified risks from the potential substitution of CBDC for bank deposits and relatively low risk assets including money market funds. Authorities could implement two broad categories of safeguards that moderate CBDC take-up and usage: (i) quantity-based safeguards; (ii) price-based safeguards (Table 4).

CBDC design options to moderate take-up Table 4

Quantity measures/ limits	Max. holding limit	Differentiated limits	Transaction limits
Price measures/ remuneration	Unremunerated / Negative remuneration	Tiered remuneration	
In-crisis measures	Gates/switching limits	Banking support	

Quantity-based safeguards would restrict the use of CBDC through imposing hard limits on the transfers and/or holdings of CBDC. Quantity limits can either be stock-based (central banks limit the amount of CBDC held by individuals/individual account holders) or flow-based (restrictions on the amount of CBDC that can be transferred within a given time period, eg a day, by an account

holder). The magnitude of the quantity restrictions could be calibrated to reflect the typical use of cash and common household payment uses.

Price-based safeguards (via remuneration or fees) could be used to disincentivise holdings of CBDC or large payments in CBDC (without restricting them). Central banks could consider paying uncompetitive interest rates on CBDC holdings to disincentivise use.[14] The remuneration system could either be a single-tier or multi-tier. In a single-tier system, holdings of CBDC would be remunerated at a rate irrespective of the amount held. In a two-tier system, up to a predefined threshold amount (q_1), CBDC holdings would pay a certain return (r_1); the amount held in excess of q_1 would be remunerated with a lower return ($r_2 < r_1$). Central banks would need to make decisions about how to apply interest rates (for example, whether on a spot amount or on a period average basis), taking account of the technical possibilities. In addition, central banks could consider charging a fee (either fixed or progressive) on transfers of CBDC that exceed a certain amount.

A combination of quantity- and price-based safeguards can also be considered. For example, a central bank could consider a two-tier remuneration system with limits on the amount of CBDC that can be transferred in a given day. Whether implemented in parallel or not, the existence of the above design features would reduce the attractiveness of a CBDC as a store of value and thus reduce the extent of disintermediation and the possible ensuing financial stability risks.

Limits could also be applied varyingly for different CBDC account holders to differentiate between businesses and households. Depending on the motivation for launching a CBDC and its framework, central banks could consider different limits or frameworks in place for households than for businesses. For example, tighter limits on business usage may moderate overall CBDC take-up while still protecting goals for widening financial inclusion.

Such limits could be imposed on a permanent basis or on a transitional basis. Some central banks may see a case for structurally limiting the extent of CBDC take-up, and risks from substitution with private money. Others may prefer to use measures only during a transitory phase to slow initial take-up and allow time for the financial system to adjust.

Calibration of any safeguards would likely need to balance moderating the risks from high and/or rapid take up of CBDC with other policy objectives for a meaningful level of usage. The illustrative analysis in Section 2 of this Report indicates that central banks could form a reasonable understanding of what level of CBDC take-up could lead to a level of bank disintermediation that they deem too high - that level may vary by jurisdiction and its financial structure. However, central banks would also likely wish to still ensure some meaningful holdings of CBDC, to meet goals such as providing the public with access to a safe means of payment in central bank money, enhancing inclusion and accessibility, or encouraging auxiliary services to be developed around the CBDC that form part of its economic benefit. Calibration of any safeguards might therefore need to avoid being too restrictive or too uniform.

Some safeguards could face implementation issues that need to be addressed. Implementation of safeguards requires access to relevant data (even if automated) and additional processing. For example, considering quantity limits on holdings, settlement of CBDC transactions

[14] In theory, the interest rate on CBDC could be negative. However, the existence of cash (which has zero remuneration) would limit this possibility

could be guaranteed only by introducing a waterfall mechanism[15] – this would require monitoring and retaining information on both holdings and transactions. Safeguards targeting CBDC transfers (such as fees or limits on the transferable amount) may not require access to as much information, as they could be applied on the transaction alone. Tiered remuneration systems may need not only implementation of the remuneration schedule itself, but also implementation of tools to prevent arbitrage (ie to prevent the emergence of a secondary market for CBDC where holders of CBDC in excess of q_1 would ask other users to hold their CBDC to avoid the lower remuneration $r_2<r_1$ (any return between r_1 and r_2 would make the transaction profitable for both parties)); such arbitrage would however be limited by operational hurdles.

In some cases, there could be legal and public policy issues to consider with respect to the premise of imposing limits and/or negative interest rates on household wealth held by the public. If the introduction of the CBDC is deemed worthwhile and its design is reasonably fit for its intended purpose, limitations on holdings may require changes to existing legal frameworks or be at odds with the general public's expectations (although limits to cash payments for security and fraud reasons do exist in some jurisdictions, such as the EU). Similarly, direct application of negative interest rates to household wealth, as opposed to indirect application passed through the banking sector, may be felt more keenly by the population. Moreover, in jurisdictions where the central bank is not otherwise contemplating negative interest rates, this tool may be impractical. Lastly, to the extent that CBDC introduced with one set of attributes leads to substitution behaviour and (more) negative interest rates are consequently applied, users may feel negatively surprised by such changes, notwithstanding related disclosures that this could occur. If holding CBDC became an exercise in active management of interest rate risk, any public benefits tied to wide access and inclusivity may be thwarted. There may also be negative economic and confidence-reducing effects associated with widely applying increasingly negative rates to household wealth in a time of stress.

5.2 Measures to manage bank run risk

In the absence of any sufficiently binding CBDC constraints,[16] periods of stress could require additional safeguards, over and above prevailing deposit insurance and crisis management frameworks in order to avoid or slow bank runs into a CBDC.

Prudential regulation is continually under review as the liquidity of bank deposits and other liabilities changes over time, for example due to technological innovations. The introduction of a CBDC or new forms of private money such as stablecoins could affect the latent risk of systemic runs, and banks may also need to adapt their own practices (Juks (2018)). For example, in the current LCR regulations, the outflow parameters for deposits provided by retail and small business customers were calibrated based on observed outflow rates during stress times that, by definition, do not account for the impact on depositors' stress behaviour in the presence of a CBDC or certain new private forms of digital money. If the introduction of CBDC increased the outflow risk for such deposits, the corresponding outflow rates may need to be reassessed to ensure that enough liquidity is available to cover potential outflows in times of stress.

[15] A waterfall mechanism would enable "excess" holdings of CBDC, arising from incoming payments that bring account holdings above a holding limit, to be automatically transferred to an account held at a bank or another intermediary.

[16] For example, in crises times price-based safeguards might be insufficiently effective because there could be no price (or only a very high price) at which individuals would be willing to hold deposits instead of CBDC.

Authorities may also need faster-acting crisis management tools. The potential for a CBDC or new private forms of digital money to increase the pace of bank runs may also necessitate examining crisis measures such as limits or controlling fund outflows from bank deposits. Central bank emergency liquidity frameworks could also be reviewed, for example to broaden collateral or access.

5.3 Other safeguards

To the extent that the introduction of CBDC or new private forms of digital money introduce new policies, regulations, rules, or new competitive advantages in service provision by different players, new concentrations of service provision may arise. Central banks should be confident that regulatory and supervisory frameworks will facilitate effective monitoring and regulation as the system evolves.

6. Conclusions

This report has focused primarily on potential risks to financial stability that could arise from the introduction of a CBDC and how to mitigate these risks. These risks need to be considered alongside the benefits and counterfactuals. A CBDC has the potential to offer new opportunities for innovation, which may benefit banks, and non-bank/third-party providers of financial services, supporting a competitive and diverse financial system. This could facilitate new opportunities for innovation and increase the resilience of the system overall – subject to authorities ensuring appropriate regulation of all parties. At the same time there is also continuing change in payment methods and emergence of new forms of privately issued digital money, some of which pose risks themselves.

The introduction of a CBDC could prompt some changes that affect the functioning of the financial system in ways similar to the introduction of new forms of private money such as stablecoins. The extent and nature of these changes would depend on take-up, which remains highly uncertain and depends on design features and attractiveness relative to deposits. The choice of a remuneration approach, and competitiveness with bank deposits, would likely be a key factor determining take-up, but non-pecuniary factors ranging from privacy to payments access could be important as well. Potential benchmarks for take-up would include factors that are specific to each jurisdiction, such as the payment attitudes and volume of currency in circulation.

A material shift from bank deposits to CBDC – which would be possible for example if the holdings of CBDCs by individual users were left unconstrained – could have a non-trivial, long-term impact on bank lending and intermediation, although these impacts may be limited for many plausible levels of CBDC take-up and if the system has time to adjust. Estimates from a simple, partial model suggest that a large shift from bank deposits to CBDC could plausibly lead to a fall in bank profitability in benign circumstances, assuming normalized monetary conditions. This could in turn affect lending conditions and/or the resilience of banks. It could imply more reliance by banks on wholesale market funding. Greater take-up levels would have a greater impact on the financial system. Moreover, the impact could be exacerbated if the response of the banking system strains the capacity of funding markets. This is more likely to occur if deposits were lost over a shorter time frame. The implications could also be larger for some types of bank business model than others.

In the context of negative interest rates, decisions around whether and how to remunerate a CBDC become more complex, given the presence of unremunerated cash, and potential

competition with bank deposits or money instruments with negative interest rates. Given the prevalence of negative interest rates and current proximity to the zero-lower bound in many jurisdictions, issues related to negative interest rates require further consideration.

Yet additionally, the existence of unconstrained CBDCs, or other digital money, as an easily accessible, safe asset could increase the risk of systemic banks runs and make money market funds or instruments more susceptible to abrupt outflows. A similar effect could arise for other sectors seen as relatively safe, notably in money markets.

That said, the presence of a CBDC could, over time, increase diversity of providers of payments and other financial intermediation services. The introduction of a CBDC could make it easier for new financial service providers to enter the market for payments services or to improve the competition amongst banks and non-banks for lending – increasing the diversity of financial service provision. This in turn, subject to appropriate regulation of all participants, could increase the resilience of financial service provision to shocks and reduce the impact of financial crises overall.

Central banks can introduce safeguards in a CBDC framework to reduce financial stability risks, notably by limiting take-up permanently or on a transitional basis. Financial stability risks also need to be carefully considered for private digital money and are potentially more challenging to manage than for CBDC. Depending on the specific rationale in a jurisdiction for pursuing CBDC, combinations of limits on CBDC holdings or transactions, or remuneration disincentives, could be deployed to moderate take-up. Calibration of limits or remuneration frameworks would need to balance moderating the take-up of CBDC, specifically substitution with private money and deposits, with allowing a CBDC to fulfil its public policy objectives. Technical solutions that allow for monitoring and implementation of limits would also need to be considered in the design phases of a CBDC, and some safeguards may be easier to implement than others.

A CBDC (or certain new forms of privately issued digital money) could also change run dynamics in a stress, and the latent level of liquidity risk banks face. Authorities might need to consider adjusting prudential liquidity requirements or other measures such as the terms of their crisis lending facilities. The potential for more abrupt flows out of money market instruments may also demand further consideration of prudential regulation in that sector. And to the extent that CBDCs encourage new entrants and the growth of non-bank financial services, authorities would need to ensure appropriate regulation of these entities.

Overall, considerable further work is needed to fully understand the full range of effects and quantify the implications for financial stability from CBDCs (including the risks and also the opportunities to enhance financial stability as the payments landscape continues to evolve), and the various design, remuneration and safeguard options. The novelty of a CBDC creates many difficult to answer questions around firstly, the extent of potential take-up, and secondly how banks, nonbanks and other providers might react to its introduction. Initial, illustrative analysis has helped shed some light on partial responses to changes in bank funding, but they have also revealed that more consideration is needed of when behavioural responses could lead to bigger impacts, and when offsetting affects might appear. Furthermore, much attention to date has been focused on risks to banks, and more consideration of the impact on money markets may be worthwhile. Observations from early CBDC launches and pilot schemes could be useful in providing more information.

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Annex A: Details of the model

Main analysis

We analyse the impact of introducing a CBDC. We assume that introducing a CBDC leads to an outflow of deposits from the banking system. This means that deposits are subtracted from the liabilities side of the banking system balance sheet, and an equivalent amount of reserves (some of their HQLA) are subtracted from the assets side of their balance sheet.

In the first, second and third rows of Table 1.A, we calculate LCR before CBDC is introduced, after CBDC is introduced but before banks take any action, and after banks adjust their HQLA, respectively.

Impact of a CBDC on the LCR and liquid assets needed to maintain the LCR — Table 1.A

Time	**LCR**	**Definition of variables**
Before deposit outflow to CBDC	$LCR_{pre} = \frac{X}{Y}$	X represents HQLA Y represents LCR stressed outflows
After deposit outflow, before banks take any action	$LCR_{interim} = \frac{X - D}{Y - sD}$	D represents deposit outflow to CBDC s represents the LCR stress factor on those deposits
After deposit outflow and banks acquiring new HQLA	$LCR_{post} = \frac{X - D + L}{Y - sD}$	L represents HQLA acquired after deposit outflow

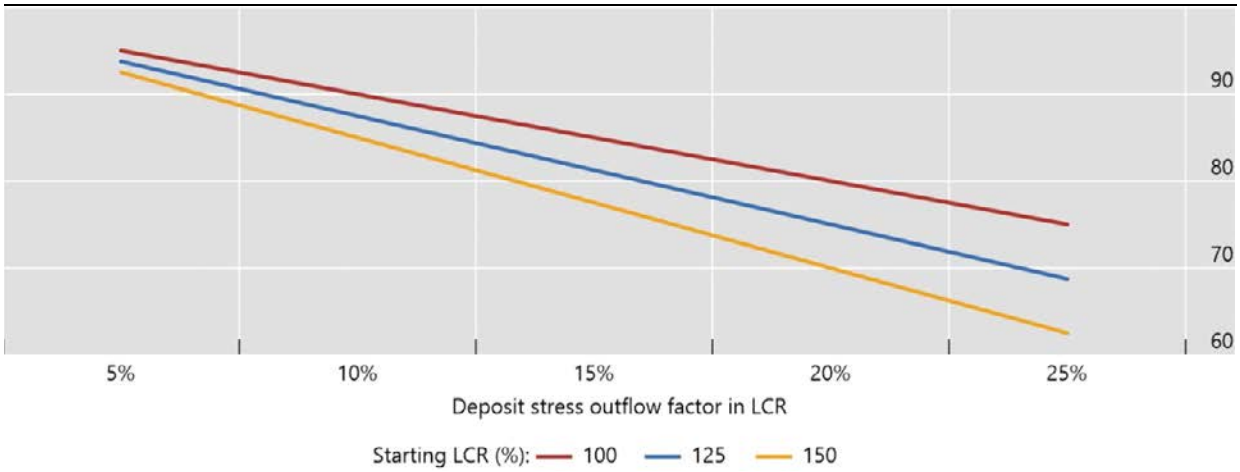
We assume that banks acquire new HQLA to maintain their actual LCR (including any management buffer over regulatory requirements) after deposit outflow. To maintain LCR at its initial level, ie $LCR_{post} = LCR_{pre}$, we must have:

$$L = D(1 - s.LCR_{pre})$$

This equation states that the additional HQLA needed to maintain the LCR at the level prior to deposit outflow to the CBDC is a function of the size of the deposit outflow (D), the stress outflow factor of those deposits (s), and the starting LCR. Graph 1.A below illustrates the amount of HQLA relative to the deposit outflow, ie L/D, needed to maintain the LCR for stress deposit outflow factors from 5% to 25% (a typical range for retail deposits) and starting LCRs from 100% to 150% (as some banks will hold excess liquid buffers).

HQLA needed to maintain LCR relative to deposit outflow

HQLA relative to deposit outflow ratio, in percent — Graph 1.A



Sources: Working Group

In this example, the HQLA needed to maintain the LCR is between around 60% and 95% of the deposit outflow. For example, a deposit outflow of USD100 billion would need USD60-95 billion of additional HQLA to maintain the LCR.

Impact of banks' actions to maintain LCRs on their balance sheet and profitability measures

One way banks could maintain their LCRs (and net stable funding ratios) is to buy HQLA in the form of government bonds, funded by long-term (eg more than 2 years) wholesale debt issuance which would have a zero stress outflow factor in the LCR. Table 2.A describes how such an action would impact on banks' balance sheets.

Impact on banks' balance sheets if banks maintain LCRs — Table 2.A

	Change in assets and liabilities
Initial change in banks' reserve asset and deposit liability	$-D$
Banks' purchase of HQLA funded with long-term wholesale debt	$D(1-s\frac{X}{Y})$
Net change in size of banks' balance sheet	$-D.s.\frac{X}{Y}=-D.s.LCR_{pre}$

This analysis shows that banks' balance sheets would contract by a small amount rather than remain constant. The intuition for this is that banks do not need to replace all the central bank reserves that left the banking system because they had already held some of those reserves against the deposits that have left the banking system. If for example, $100bn deposits left the banking system then for the stressed outflow and starting LCRs in Graph 1.A, the banking system would contract by around $5-40bn, which is small relative to the size of the banking system.

Next, we calculate how banks' net interest income (NII), NIM and RoE change if they adopt the aforementioned measures, ie buying HQLA against long-term wholesale funding, while keeping LCR fixed

at the level prior to introducing a CBDC. For this, we start by introducing a simplified banks' balance sheet below:

Balance sheet of the banking system before CBDC

interest earned	Assets			Liabilities		interest paid
r_1	HQLA	A_1	L_1	Deposits		i_1
r_2	Loans	A_2	L_2	Wholesale funding		i_2
r_3	Other	A_3	C	Capital		

We can write the NII, NIM, RoE and return on assets (RoA) as follows:

$$NII_{pre} = (r_1 A_1 + r_2 A_2 + r_3 A_3) - (i_1 L_1 + i_2 L_2)$$
$$NIM_{pre} = \frac{NII_{pre}}{A}$$
$$RoA_{pre} = \frac{NII_{pre}(1-T)}{A}$$
$$RoE_{pre} = \frac{NII_{pre}(1-T)}{C}$$

where $A \equiv A_1 + A_2 + A_3$ is the total amount of assets, RoE is calculated post-tax, and T is the tax rate for banks.[17]

After CBDC is introduced and banks acquire HQLA against long-term wholesale funding (including secured and unsecured), their balance sheet turns into the following:

Balance sheet of the banking system after CBDC

Assets		Liabilities	
HQLA	$A_1 - \mathrm{D.s.LCR}_0$	L_1-D	Deposits
Loans	A_2	$L_2 + \mathrm{D}(1 - \mathrm{s.LCR}_0)$	Wholesale funding
Other	A_3	C	Capital

Again, we can calculate new values of NII, NIM, RoE and RoA as follows:

$$NII_{post} = \Big((r_1 + dr_1)\big(A_1 - D.s.LCR_{pre}\big) + r_2 A_2 + r_3 A_3\Big)$$
$$-((i_1 + di_1)(L_1 - D) + (i_2 + di_2)(L_2 + D(1 - s.LCR_{pre}))$$
$$NIM_{post} = \frac{NII_{post}}{A - \mathrm{D.s.}LCR_{pre}}$$
$$RoA_{post} = \frac{NII_{post}(1-T)}{A - \mathrm{D.s.}LCR_{pre}}$$
$$RoE_{post} = \frac{NII_{post}(1-T)}{C}$$

[17] To calculate NIM, we need to divide NII by total interest-bearing assets, but here, we assume all assets are interest bearing, so total assets and total interest-bearing assets are identical.

Next, we calculate the change in these profitability measures one by one. Before that, we show the variable names, values, parameters, and source of data in Table 3.A. We do not have consistent data across all parameters for developed countries, but we believe that the results are useful to illustrate the potential impact. The analysis can also be replicated by individual country.

Model variable names, values, parameters, and source of data Table 3.A

Variable name	**Value**	**Parameter**	**Source**
Spread between HQLA and deposit rates	0.00%	$m_b = r1 - i1$	Average of the spread between repo rate and deposits (3-month) for banks of G7 plus Switzerland for 2010-2020, from BIS
Loans to assets	58.00%	A_2/A	Average across countries for 2016, from BIS (CGFS publication, Table 1.10)
Net Interest Income	3.52%	NII/A	Average of NII to interest-earning assets, for banks in G7, Sweden and Switzerland for 2010-2020, from BIS
Return on equity	7.50%	RoE	Average of RoE for 2016 from BIS dataset (CGFS publication, Table 1.27)
Net Interest Margin	2.30%	NIM	Simple average across countries for 2016 from BIS dataset (CGFS publication, Table 1.30)
Deposits stress factor	15%	s	Broadly representative of a blend of retail and corporate deposits
Liquidity Coverage Ratio	125%	LCR	Broadly representative of the US and European banks
Spread between 5-year wholesale and deposit rates	0.63%	m_a	Average over 2017-2021 across G7 (excluding US) plus Sweden

Impact on NII

$$\Delta NII = NII_{post} - NII_{pre} = -r_1 D.s.LCR_{pre} + i_1 D - i_2 D\left(1 - s.LCR_{pre}\right)$$
$$+dr_1(A_1 - D.s.LCR_{pre}) - di_1(L_1 - D) - di_2\left(L_2 + D\left(1 - s.LCR_{pre}\right)\right)$$

where:

dr_1, di_1 and di_2 denote the change in r_1, i_1 and i_2, respectively.

For the rest of the analysis, we assume $dr_1 = di_1 = di_2 = 0$.

That is, the rates do not change following the introduction of a CBDC. Using our framework, it is easy to do various sensitivity analyses for the cases that rates change too.

Given this assumption, we can write:

$$\Delta NII = D\left((i_1 - i_2) - s.LCR_{pre}(r_1 - i_2)\right) = D\left(-m_a - s.LCR_{pre}(m_b - m_a)\right)$$
$$= -\left[\left(1 - s.LCR_{pre}\right)m_a + s.LCR_{pre}.m_b\right]D$$

where:

$m_a \equiv i_2 - i_1$ denotes the spread between wholesale and deposit funding rates, and
$m_b \equiv r_1 - i_1$ denotes the spread between HQLA and deposit rates.

Equivalently:

$$\frac{\Delta NII}{NII} = -\left[\left(1 - s.LCR_{pre}\right)m_a + s.LCR_{pre}.m_b\right]\frac{D/A}{NII/A}$$

In the numerator, we have the initial, relative change in the size of the balance sheet, and in the denominator, we have the net interest income relative to the size of the balance sheet.

Impact on RoE

$$\Delta RoE = \frac{1 - T}{C}\Delta NII = RoE_{pre}\frac{\Delta NII}{NII_t}$$

Like previous figures, Figure 3 illustrates the change in the RoE.[18]

Impact on NIM

$$\frac{NIM_{post}}{NIM_{pre}} = \frac{\frac{NII_{post}}{NII_{pre}}}{\frac{A - \mathrm{D.s.}LCR_{pre}}{A}} = \frac{1 + \frac{\Delta NII}{NII_{pre}}}{1 - \frac{\mathrm{D.s.}LCR_{pre}}{A}}$$

If $\frac{\mathrm{D.s.}LCR_{pre}}{A}$ is small, we will have:

$$\Delta NIM = NIM_{pre}\frac{NIM_{post} - NIM_{pre}}{NIM_{pre}} \cong NIM_{pre}\left(\frac{\Delta NII}{NII_{pre}} + \frac{\mathrm{D.s.}LCR_{pre}}{A}\right)$$

[18] Note that from a bank examiner's point of view, RoA might be more important than RoE, as the latter is more relevant to equity holders not to the regulator. However, in our framework, the percentage change in RoA is equal to the percentage change in the NIM, so we don't report results for RoA separately.

Potential impact on loan rates

In this section, we examine the case in which banks aim to maintain their NII (equivalent approximately to maintaining their NIM, as NIM denominator changes slightly) by changing their loan rates. Crucially, we assume that lending volumes could be maintained. This assumption is not realistic, but the goal is to get a sense of the size of change in the lending rates, not to predict the exact change.

Denote by x the increase in the loan rate needed to maintain NII. Then, x is given by

$$\Delta NII = D\big((i_1 - i_2) - s.LCR_t(r_1 - i_2)\big) + xA_2 = 0, \text{ so}$$
$$x = \big[(1 - s.LCR_{pre})m_a + s.LCR_{pre}.m_b\big]\frac{D}{A_2}$$

The first term relates to the cost of the switch in funding from deposits to wholesale funding. The second term relates to the cost of the slight reduction in HQLA needed for the new steady state balance sheet, if the HQLA rate is above the deposit rate (ie if bank deposit rates are below the central bank policy rate). This is small if the outflow factor s is small and/or if the deposit spread to the policy rate is small.

The lines in Graph 3 (in the main report) are relatively insensitive to plausible variations in s, LCR and the spread between deposit rates and the policy rate (m_b). To adjust for term premia, we can assume that the long-term wholesale funding rate and loan rates are floating rate (including fixed rate funding/loans that are swapped into floating).

In these illustrations, the maximum impact on loan rates is around 0.7% pts for a deposit outflow of 25% relative to the size of the assets and if the wholesale funding rate is 2% pts higher than the deposit rate.

Annex B: Expert group members

Chair	Fabio Panetta (European Central Bank)
Bank of Canada	James Chapman Mohammad Davoodalhosseini
European Central Bank	Katrin Assenmacher Nicola Branzoli (Italy) Petya Radulova Tamarah Shakir
Bank of Japan	Hirotaka Inoue Kazushige Kamiyama Amika Matsui Megumi Nanya (until August 2021) Takeshi Yamada
Sveriges Riksbank	Carl Andreas Claussen Tobias Lindqvist Björn Segendorf
Swiss National Bank	Reto Nyffeler
Bank of England	Nick Butt Jeremy Leake Michael Yoganayagam
Board of Governors of the Federal Reserve System	Melissa Leistra
Bank for International Settlements	Giovanni Lombardo

Thanks also go to Katie Fortune (Bank of England).