INTERNATIONAL MONETARY FUND

Central Bank Digital Currencies and Financial Stability: Balance Sheet Analysis and Policy Choices

Prepared by Romain Bouis, Gaston Gelos, Paavo Miettinen, Fumitaka Nakamura, Erlend Nier, and Gabriel Soderberg

WP/YY/226

2024
OCT

WORKING PAPER

IMF Working Paper
Monetary and Capital Markets

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October 2024

ABSTRACT: This paper offers a comprehensive analysis of the implications for financial stability of a central bank issuing a digital currency to the public at large. We start with a systematic analysis of balance sheet changes that arise from the new liability for the central bank and the banking system, and examine how they depend on preconditions, central bank choices, and banking system responses. Based on this, we discuss the range of implications for financial stability that may arise in steady state, in the context of adoption, and in crisis times. Threats to financial intermediation in steady state arise mainly in situations where the central bank balance sheet expands, and triggers adjustment mechanisms that lead to more costly or less stable funding of the banking system, while in crisis times run risk may increase. Our analysis of policy choices to control these effects considers macroprudential policy, and an expansion of central bank lending to commercial banks, but finds that a main contribution needs to come from a design of the CBDC that encourages its use as a means of payment rather than a store of value.

RECOMMENDED CITATION: Bouis, R., Gelos, G., Miettinen, P., Nakamura, F., Nier, E., and Soderberg, G. (2024). Central Bank Digital Currencies and Financial Stability: Balance Sheet Analysis and Policy Choices. Working Papers WP/24/226, International Monetary Fund.

JEL Classification Numbers:	E42, E58, G01, G21
Keywords:	Central Bank Digital Currency; Financial Stability; Balance Sheets; Disintermediation; Bank Runs
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WORKING PAPERS

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[1] The paper benefited from excellent comments from Marco Casiraghi, Christopher Erceg, Federico Grinberg, Marco Gross, Dong He, Charles Kahn, Inutu Lukonga, Marcello Miccoli, Julia Otten, Tao Sun, Pawel Zabczyk, and seminar participants at the IMF. The authors are grateful for research assistance provided by Jianhong Liu and Jahanvi Singh and production assistance provided by Sara Durrani, Sandra Paulaviciene, Ravaka Prevost, and Joanna Zaffaroni.

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Glossary

BIS ..... Bank for International Settlements

CBDC ..... Central Bank Digital Currency

ECB ..... European Central Bank

EU ..... European Union

FSB ..... Financial Stability Board

FX..... Foreign Exchange

GFC..... Global Financial Crisis

HQLA ..... High-Quality Liquid Assets

IFS..... IMF International Financial Statistics

IT ..... Information Technology

LCR ..... Liquidity Coverage Ratio

LOLR..... Lender of Last Resort

LR..... Leverage Ratio

LTROs..... Long-Term Refinancing Operations

MFS..... Monetary and Financial Statistics

NBFI ..... Non-bank Financial Institution

NFC ..... Non-Financial Corporation

NIM..... Net Interest Margin

NSFR ..... Net Stable Funding Ratio

ROE ..... Return on Equity

US ..... United States

Executive Summary

This paper offers an evaluation of the financial stability implications of the issuance of retail central bank digital currencies (CBDCs) to help inform policy choices to mitigate potential adverse impacts. Overall, financial stability implications of issuing a retail CBDC depend on (1) the size of the issuance, (2) initial conditions, and (3) the reactions of the banking sector and the central bank. Should there be material adverse effects, it is important that policy measures be taken to ensure that the desired benefits of a CBDC can be realized in a manner that addresses potential risks.

We first provide a range of scenarios that trace how the balance sheets of the commercial banking system and of the central bank may respond to the issuance of digital money, thereby affecting the sources and stability of funding, profitability, and the provision of credit of the financial system. This scenario analysis highlights that the adverse effects on the banking system become larger when (1) the replacement of deposits is greater, (2) commercial banks do not hold excess central bank reserves, and (3) central banks are not willing to increase the supply of reserves beyond existing collateral requirements.

We find that adverse implications for financial stability can arise in steady state, but that they may be more material when network effects result in rapid adoption, as well as in crisis times when there is a risk of digital runs into the CBDC. Importantly, policy makers can contain detrimental effects from CBDC by choosing adequate policy options, including adopting CBDC designs that encourage its use as a means of payment, rather than as a store of value.

Financial stability implications do not arise when the CBDC largely replaces physical cash. When the CBDC instead competes with deposits, the implications are still going to be largely contained if the banking sector holds ample excess reserves that can be drawn down in exchange for the CBDC. Adverse effects can arise mostly in scenarios where the central bank balance sheet expands, and commercial banks increase more costly and or more volatile funding to help generate additional reserves.

We offer a comprehensive examination of central banks' policy options to mitigate the adverse effects on financial stability, were they to be material. We explore whether macroprudential policy tools could help contain any adverse financial stability effects. We also examine the scope for an expansion in central bank lending to the commercial banking system, such as through changes to central bank collateral policies. We finally assess how the appropriate design of CBDC can mitigate adverse financial stability implications.

We find that mitigating the emerging risks from CBDC by macroprudential or financial sector regulatory policies alone is likely to be difficult. Macroprudential policy can increase banks' resilience but cannot provide much relief if the CBDC puts pressure on bank liquidity or disrupts credit intermediation. Financial stability concerns arising from a greater role of non-bank financial institutions (NBFIs) in banks' funding underscore the need to make progress in their macroprudential regulation. However, given the diversity of NBFIs, achieving this objective is complex, with the international nature of some NBFIs adding additional challenges.

Expanding central bank lending operations can help reduce the detrimental financial stability impacts, in particular in crisis times when the central bank will want to provide emergency liquidity to banks that are subject to runs into the CBDC. Greater use of ex-ante positioning of illiquid assets and applying haircuts on these assets in emergency operations is worth considering. However, loosening central bank lending standards in

normal times or in steady state, such as by admitting a broader set of collateral or aiming for longer loan tenors in open market operations can expose central bank balance sheets to substantial additional risks.

CBDC design features hold most promise for alleviating financial stability concerns. Designs that encourage use of the CBDC as a means of payment, rather than as a store of value, are likely to maintain benefits while avoiding costs for financial stability. Such design elements include zero- or negative remuneration, limits to holding CBDC, and a high degree of interoperability with the bank-operated payment system. These features can ensure that the CBDC is used primarily for transactions, while containing risks to credit disintermediation as CBDC adoption advances. CBDC designs that foster further developments in deposit-based payment solutions — such as tokenized deposits — could also preserve the singleness of money while containing negative effects on financial stability.

1. Introduction

Central banks all over the world are exploring the potential benefits of CBDCs. Their policy objectives differ according to country circumstances but range from modernizing the payments system and making it more resilient, to ensuring trust in the monetary system and monetary sovereignty (Soderberg et al., 2022). According to Kosse and Mattei (2023), over the course of 2022, more than 90 percent of central banks engaged in some form of CBDC work, and around two thirds of central banks considered that they were likely to or might possibly issue a retail CBDC in either the short or medium term.[2]

Central banks and ministries of finance have established a firm principle that potential issuance of CBDC should "do no harm" to the existing financial system (Bank for International Settlements (BIS) Innovation Hub (2021a), G7 (2021)). A primary concern, identified in a broad literature, is that issuance of CBDC could result in adverse effects on the smooth provision of credit to the economy. While "no harm" is not meant to be interpreted as "no impact" (BIS 2021a), any potential issuance of CBDC will need to assess whether such risks can be mitigated to the point that its issuance would be consistent with the "do no harm" principle. Indeed, IMF (2023c) stressed the importance of investigating the macro-financial implications of CBDC to ensure that widespread adoption of digital money fosters domestic and international economic and financial stability. However, while some existing papers consider relevant aspects and implications for financial stability (e.g., BIS (2021b)), the existing literature is missing a full analysis of the potential impacts on the financial sector as a whole, including the banking sector, the central bank, and nonbank financial institutions (NBFIs).[3]

We contribute by considering the implications of a retail CBDC for financial stability using the analysis of sectoral balance sheets as an organizing frame. When creating these scenarios, we make only three reasonable assumptions: (1) central banks issue CBDC against other central bank liabilities (either cash or reserves) rather than by way of a "helicopter drop,"[4] (2) there is positive demand for CBDC, and (3) issuance of CBDC occurs through the banking system.

While several existing paper offer some examples of how a central bank balance sheet can change as a result of the issuance of CBDC, we offer a more systematic account of the potential ways in which both the central bank's and commercial banks' balance sheets can adjust to the issuance of CBDC.[5] This analysis can

[2] This share of CBDC engagement varies across the literature. For example, Stanley (2022) states that more than half of the world's central banks are in research or development stages as of July 2022.

[3] BIS (2021b) investigates the potential risks to financial stability that could arise from the introduction of a CBDC and how to mitigate these risks. Relative to BIS (2021b), this paper uses comprehensive balance sheet scenarios for the central bank and the banking sector to discuss the financial stability implications, depending on the amount of the deposit replacements, and the reactions of commercial banks and central banks. Furthermore, the paper also points out new financial stability risks, such as those arising from greater interconnectedness to the NBFI sector and the foreign sector and discusses implications for macroprudential policies.

[4] Obviously, a helicopter drop would be inflationary.

[5] Juks (2018), Bucholtz et al. (2022), and Auer et al. (2024) study the effects of CBDC on banks using the Swedish, Israeli, and Italian banking sectors as an illustration, and discuss the changes in their funding profiles. Adalid et al. (2022) and Meller and Soons (2023) investigate the implications for the financial sector based on scenarios for the issuance of digital euros. Carapella et al. (2024) examine the financial stability implications of issuing digital dollars, with the primary focus on stressed times. Armas and Singh (2022) provide several scenarios for the issuance of digital monies. Compared to these studies, this paper examines the financial stability and macroprudential implications more comprehensively based on the reactions from commercial banks and central banks. In addition, this paper does not focus on a specific country and discusses implications for financial stability that can be applied to any country depending on its characteristics.

be applied to examine a range of starting points that may differ across countries, alongside differences in the desired effects of the CBDC.

This analysis shows how potential adverse implications for the existing financial system depend on (1) the amount of CBDC being issued, (2) the preconditions relating to the existing sectoral balance sheets prior to the issuance of the CBDC, and (3) basic assumptions on how banks and the central bank interact in the issuance of CBDC.[6] Building on this, we draw out and explore the range of financial stability implications that can arise across the relevant outcomes. We finally provide a comprehensive discussion of central bank policy choices to mitigate any adverse impacts, including the use of macroprudential policy, an expansion in provision of central bank liquidity to the banking system, and options for the design of CBDC.

We focus on the possible implications of central banks issuing a "retail" CBDC on financial stability, that is, a CBDC that is available for everyday payments by households and firms. When a CBDC is issued to the public at large, this may have stronger implications for the functioning of the financial system compared to a "wholesale" CBDC that is issued only to banks and NBFIs alongside existing central bank reserves. For retail CBDC the main potential risks revolve around the conversion of banks' deposits into CBDC, as CBDC instead of bank deposits is used for payment purposes by households and firms.

We first summarize the potential benefits for central banks of issuing such a widely accessible digital version of the local currency. We then turn to an analysis of potential adverse effects on financial stability. However, a formal welfare analysis falls outside the scope of this discussion. Moreover, we assume throughout that the central bank holds on to the plan to issue a retail CBDC, while it is interested in reducing the potential adverse effects of such a move.

We do not cover aspects related to possible effects on the effectiveness of monetary policy, nor do we provide a comprehensive treatment of the financial stability concerns related to private digital money that may well in part motivate the issuance of the CBDC. Additionally, alternatives to CBDC issuance for achieving central bank objectives, such as fast payment initiatives, are outside the scope of the discussion here and are discussed more fully elsewhere (e.g., Das et al., 2023). To gain insights into financial stability implications, we first provide a range of stylized scenarios that trace how the balance sheets of both the commercial banking system and that of the central bank respond to the issuance of digital central bank money. This analysis tracks how the funding of the financial system, as well as its profitability and ability to provide credit to the real economy, could evolve following the introduction of a CBDC.

Although the adoption of CBDC has been slow in some countries that have already issued them, once a critical mass of users is reached and network effects for CBDCs are achieved, a rapid wider adoption cannot be ruled out. Therefore, policy makers need to keep this possibility in mind and explore ways to mitigate the risk of disruption during the adoption process.

A key conclusion of the scenario analysis is that the potential for adverse effects on the banking system depends on whether the central bank's own balance sheet expands from the CBDC issuance. In scenarios where the issuance of the CBDC is against existing physical cash, or leads to a drawdown of existing excess reserves, the implications for the functioning of the existing financial system are generally likely to be mild (see also Infante et al. 2023, and Meller and Soons, 2023). In scenarios where instead the issuance of the CBDC

[6] Retail CBDC is available for the general public, which distinguishes it from wholesale CBDC which is only available for eligible financial institutions.

leads to an expansion of the central bank's balance sheet, adverse effects can arise when this leads banks to use more costly or volatile wholesale funding from the central bank or NBFIs.[7] Moreover, banks' competitive reactions to the issuance of the CBDC can lead to an increase in rates charged on loans to households and firms, ultimately reducing the volume of credit to households and firms. While some of these effects can occur in a new steady state, in which the CBDC coexists with traditional deposits, they can be magnified when adoption turns out to be more rapid than foreseen, or in a crisis scenario when banks find it difficult to replace funding lost in a digital run.

Against this background, the paper discusses potential central bank policy options to mitigate any adverse effects on financial stability. This includes potential macroprudential mitigants, expansion of central bank lending operations, and options for the design of CBDC.

A key mitigating policy comes from the design of the CBDC. Designs that encourage use of the CBDC as a means of payment, rather than as a store of value, are likely to be useful to increase benefits while avoiding costs. This amounts to making the CBDC widely available (extensive margin), while inducing households and firms to hold small amounts for making retail payments (intensive margin). Design elements that help achieve this include quantitative restrictions (caps), maintaining zero remuneration of CBDC balances, and ensuring interoperability with bank deposits. Although these elements are technically feasible, some consideration should be given on how to make them effective. For instance, quantitative restrictions, such as holding caps, can work better when the CBDC is not remunerated, since the incentives for circumvention by households wanting to hold several wallets may otherwise be strong.

Macroprudential policy can increase banks' resilience, for example by imposing stronger capital positions ahead of the introduction of the CBDC. However, we find that mitigating the emerging risks by macroprudential or financial sector regulatory policies alone is likely to be difficult. This is because introducing the CBDC may erode prudential liquidity metrics that a tightening of requirements can do little about. In addition, while financial stability concerns from a greater role of NBFIs in banks' funding underscore the urgency of achieving progress in their macroprudential regulation, this is likely to be challenging.

An expansion of central bank lending operations can help reduce the detrimental financial stability impacts, especially in crisis times, when the central bank will want to provide emergency liquidity to banks that are subject to runs into the CBDC. However, changes to central banks' liquidity provision in normal times and to the system as a whole are more difficult to entertain since a broader set of collateral and longer loan tenors for such operations can also expose central bank's balance sheet to additional risks.

We begin by summarizing the range of benefits that issuing a CBDC can have for central bank objectives (Section 2). We then present the analysis of CBDC adoption scenarios (Section 3) and provide a full discussion of the range of adverse financial implications that can arise from these scenarios (Section 4). Against this backdrop we consider several possible risk-mitigating policies that could contain such impacts, including macroprudential policies, monetary policy, and central bank lending operations in normal course and in crisis situations, and options for the design of the CBDC that reduce the scope for the CBDC to be used as a store of value (Section 5). Section 6 concludes by summarizing policy implications.

[7] Wholesale funding is defined as funding other than retail deposits, including potentially market-based funding as well as deposits from large corporates.

2. Potential Benefits of Retail CBDC for Central Bank Objectives

Both benefits and costs should weigh on a central bank's decision to issue a retail CBDC, and we therefore briefly survey the former, before turning to potential adverse effects and their mitigation. When CBDC improves the efficiency of the payments system and promotes the use of digital currency issued by the central bank, this can generate benefits for central bank objectives in several ways, depending on country preconditions. Some of these benefits relate to efficiency gains from using a faster and more reliable payment platform, others stem from benefits for monetary and financial stability. They can depend on the prevailing technology for retail payment such as the preponderance of cash use or the expected future evolution of the system, including the future rise of private digital moneys.

Of course, reaping these benefits may also require investment on the part of both the central bank and the commercial banks. Where these costs are substantial, the establishment and adoption of payment systems that enable the use of CBDC may be slowed down. However, the costs of establishing the system and of promoting its use are not considered further in this paper.

Reducing the Costs of Producing and Handling Cash

A CBDC can be designed to reduce the amount of physical cash held and used in the economy. In cash-based economies, the production of suitable notes and coins can be costly for central banks who need to invest in keeping the design of the notes difficult to counterfeit. Moreover, the distribution of notes across the economy—from the central bank or its printing houses onto commercial banks and ultimately to households and firms—can generate deadweight costs for both the central bank and the commercial banking system because of the need for security to protect against theft across the whole chain. Moving to a digital form of currency can therefore bring substantial savings in costs, especially in economies with a prevalence of cash usage.

Fostering Financial Inclusion

CBDC could be designed to foster financial inclusion, again especially in cash-based economies. Barriers to financial inclusion include, but are not limited to high costs of financial services provision, such as the geographical remoteness of parts of the population, the lack of identity credentials and established credit histories of potential borrowers, as well as factors constraining the demand for financial services, such as lack of trust in financial services, or low financial literacy.

While not a "silver bullet" that can solve these issues alone, a CBDC could be designed to reduce some of these barriers, and thereby help to increase financial inclusion. For instance, CBDC could be designed to operate in offline environments, on feature phones and/or stored-value cards, and in remote areas where the private sector may not be willing to offer service because of lower profitability. Also, the CBDC could be designed so that credit histories can be built up based on transactions made using the CBDC. It is also possible to consider designs where each CBDC wallet that is created automatically also generates a simple bank account into which surplus money can be transferred for savings purposes. CBDC could also be designed

and marketed to promote access to digital money in remote areas. If CBDC helps increase financial inclusion in these ways, the banking sector could become stronger and deposit funding could increase.[8]

Improving the Payment Infrastructure

CBDCs can improve the efficiency and resilience of deposit-based payment infrastructures, either directly or indirectly. Directly, a CBDC can introduce a new digital way to make payments, which could reduce the deadweight costs associated with the management of checks and other retail payment systems that are ultimately based on bank deposits, such as credit cards. It could also increase the resilience of the payment system, through introducing a "back up" means of payment to other digital payment systems or cash (Williamson, 2022). The CBDC can finally foster competition between payment systems, adding incentives for incumbents to improve their services and lower their prices. In particular, a CBDC can be used to lessen the pricing power that financial intermediaries can derive from the network effects of deposit-based payment systems (see Chiu et al., 2023). It can also reduce distortions that arise from high switching costs between bank accounts that shift economic surplus from households to the financial sector (Kahn, 2022).[9]

Maintaining Monetary Sovereignty

For some central banks, an important motivation for issuing CBDC is to preserve their monetary sovereignty in the face of an increased proliferation of private digital monies. Unless the central bank provides an efficient and easy way to use digital money, private and foreign digital money could potentially replace domestic incumbent currencies (cash and deposits) and dominate the market, especially in countries where the central bank does not have sufficient credibility (Brooks 2021, Cunliffe 2023). In these economies, there is a risk of "currency substitution," where private stablecoins[10], including those that are pegged to a hard currency, become so attractive to consumers that they crowd out the local currency. This can weaken the transmission of monetary policy, and lead to the central bank losing control of monetary conditions and ultimately price stability. In order to maintain monetary sovereignty central banks may therefore issue a digital version of their own currency.[11]

Reducing Financial Stability Risks from Private Stablecoins

The issuance of a CBDC can also be motivated by a desire to reduce adverse financial stability effects of a proliferation of private digital monies, such as stablecoins.

Stablecoin managers have an incentive to invest in higher yielding assets, but the credibility of the stablecoin arrangement can come into question when these assets fall in value. This can lead to run-like

[8] The Brazilian instant payment ecosystem (Pix) can serve as an illustration of this. This system was provided for use by households by the Central Bank of Brazil starting from 2020 and achieved rapid adoption as a result of convenience of use. In the process, it increased the number of checking accounts held in the population, as opening such accounts is necessary to use PIX, incentivizing households to open banking accounts and use banking services (see Das et al., 2023). Similarly, when the distribution of CBDC to the population involves offering or mandating a checking account, the volume of such accounts could increase, with positive implications for bank intermediation.

[9] For example, Gondat-Larralde and Nier (2006) find that switching costs are a key factor limiting competition for deposits among banks in the UK.

[10] Stablecoins are privately issued digital money where the stability of coins is derived either from a backing with conventional assets or the use of an algorithm.

[11] If should be noted that where households and firms prefer stablecoins including those denominated in hard currencies, because households lack trust in the local currency, a CBDC that is a digital version of that local currency could struggle to find traction.

behavior and fire sale dynamics as the issuer tries to keep up with redemptions. Moreover, the inability of central banks to provide liquidity to issuers and users of private digital money in times of stress would diminish the central bank's capacity to contain fire sales. As a result, the widespread usage of digital money could make financial markets more vulnerable during stress periods, creating the potential for spillovers to the traditional financial system.

CBDCs could be used to remove some of the financial stability concerns in jurisdictions where stablecoin popularity is increasing. By providing an attractive alternative method of payments, central banks may limit the volume of the private stablecoins and mitigate the associated adverse effects on financial stability.

However, the prospect of the CBDC containing the market share of stablecoins can also be subject to limits. Importantly, the CBDC can only be made available in local currency, while many stablecoins are issued in US Dollars. In countries where residents have a strong preference to hold foreign currency assets, this may limit the success of a CBDC.[12] Moreover, if the central bank issuing the CBDC is worried about potential disintermediation from issuing the CBDC, it might want to limit the scale of its own issuance, giving private issuers of digital money a competitive advantage. An important alternative way of mitigating financial stability risks from a proliferation of stablecoins is to subject these structures to robust regulation and supervision, and to ensure they do not gain the status of legal tender (see IMF 2023b).

In countries where stablecoins are unlikely to overtake the role of bank deposits, CBDC issuance would benefit domestic financial stability less, as issuing the CBDC entails its own risks to financial intermediation. Moreover, in some countries, commercial banks are experimenting with tokenized deposits using digital technologies, in addition to different fast payments initiatives.[13] Since these alternatives complement the commercial banking system, if private monies evolve along this path, there may be less need for a CBDC from the domestic stability point of view.

To summarize, a CBDC can have several potential benefits for central banks and can increase social welfare. These benefits depend strongly on the existing state of retail payment systems. For instance, where the economy is largely cash-based, a reduction of the costs arising from cash use and an increase in financial inclusion are likely in focus. The benefits will present differently in economies where the use of cash is already limited and much of the volume of payments is made using deposit-based payment systems, such as through credit and debit cards, or where there is a threat of a proliferation of private digital moneys.

In turn, however, issuing a CBDC may also pose risks to the smooth functioning of the financial system, depending on preconditions, the scale of the planned issue, and the design of the system. It is then important to consider both benefits and costs, including financial stability risks. It is possible that the benefits of a CBDC are large, while the costs to financial stability are small, for instance, because the CBDC primarily replaces cash, and could also lead to greater financial inclusion amongst the unbanked population. Another possibility is that the benefits of a CBDC are large, while costs to financial stability are also found material In the latter case, it is prudent for implementation to carefully consider and build in policies to mitigate the potential risks, as discussed in the dedicated section below.

[12] Nigeria is an example of a country where a CBDC uptake has been slow since its launch, even as dollar-denominated stablecoins are thriving. See IMF (2022).

[13] Tokenized deposits refer to digital versions of conventional commercial bank deposits.

3. CBDC Issuance Scenarios: Impact on Financial Sector Balance Sheets

In this section, we consider the effects of CBDC issuance on both the central bank's and the banking sector's balance sheets under various scenarios. Given the considerable uncertainty about the strength of the future demand for CBDC, we present a range of scenarios that differ in the uptake of CBDC by households. We then show that the volume demanded is an important determinant of financial stability effects.

However, a key objective of this scenario analysis is to consider how the potential effects on financial stability depend not only on the amount of the CBDC being issued, but also on preconditions, in terms of the structure of the balance sheets of the central bank, and the commercial banking sector, as well as on second-round effects from competitive reactions by the commercial banking sector to the issuance of the CBDC.

This analysis highlights that, although some scenarios anticipate significant adverse implications for the banking sector, detrimental effects due to the issuance of CBDC may well be contained in many economies. For instance, in economies with sizable amounts of physical cash, the introduction of a retail CBDC may lead to substitution of physical for digital cash, with very mild, if any adverse impacts on financial intermediation. Similarly, in economies where the banking sector carries large amounts of excess reserves, CBDC issuance would only lead to a reduction of these excess reserves, without the need for banks to replace any lost deposits, thereby keeping adverse financial stability implications well contained.

The scenario analysis also acknowledges, however, that the full effects on financial stability of introducing a CBDC will depend on endogenous reactions of agents in the economy to the existence of this new central bank liability, including competitive responses by the banking system and responses by households and firms in the context of adoption and in periods of stress. These issues are only partly embedded in the scenarios themselves and are discussed in greater depth in later sections.

Baseline Scenario

The baseline scenario – before the issuance of the CBDC – uses illustrative values (in an arbitrary unit) of balance sheet components of the consolidated banking sector and of the central bank.

As shown in Table 1, the assets of the consolidated banking sector consist of loans to the private sector, reserves held with the central bank, government bonds, and other securities. In our stylized balance sheets, government bonds are distinguished from other securities, since they are typically the only securities that can be used as collateral by banks when borrowing from the central bank.[14] Also, banks are subject to minimum reserve requirements, which determine the amount of excess reserves that they hold on deposits with the central bank. Liabilities of the consolidated banking sector consist of deposits, central bank lending, debt issued, other short-term liabilities, and capital. Deposits are the primary and cheapest funding source, representing most of banks' total liabilities.

[14] In practice, some central banks accept corporate bonds and high-rating loans as collateral, but for the sake of simplicity, we assume here that only government bonds can be used as collateral.

The balance sheet of the central bank is typically smaller than that of the commercial banking system, with cash and commercial bank reserves being its main liabilities, and outright securities holdings as well as lending to the commercial banking system the main assets. Details are described in Annex I.

Table 1. The Balance Sheet in the Baseline Scenario (without CBDC)

Consolidated banks		Central Bank	
Assets	**Liabilities**	**Assets**	**Liabilities**
Loans	Deposits	Lending	Cash
GB (gov. bond)	CB lending	Securities	Reserves
Reserves	Debt issued	Others	Others
Others	Others		
	Capital		

SOURCE: Authors' elaboration.

CBDC Replacement Scenarios

We consider stylized scenarios that trace the changes in the balance sheets of the central bank as well as of the commercial banking system that may result from the introduction of the CBDC.[15] Consideration of these balance sheet changes lays the ground for a discussion of potential ensuing vulnerabilities (in Section 4, below), including risks that may arise as the system adapts to the initial change, or comes under pressure as a result of aggregate stress after the adoption of the CBDC. Differences in the volume of issuance are assumed to reflect variations in consumer demand for the CBDC, which we take as given when considering their impact on balance sheets.

The first scenario (Scenario 0) corresponds to the case where CBDC replaces cash—the original direct liability of the central bank. That is, to obtain the CBDC, the household hands over an equal amount of cash to the central bank—or to a bank that conducts the exchange on behalf of the household. In all other scenarios, households draw down commercial bank deposits to purchase CBDC. To complete such a purchase, in those cases, the households' bank buys the CBDC on behalf of the customer from the central bank and pays for the CBDC using its existing reserves at the central bank.

In these other scenarios (other than Scenario 0), households' increase in CBDC holdings leads to a deposit reduction in the commercial banking system, which yields changes in banks' balance sheets that are very similar to what happens when households increase their cash holdings by reducing deposits. As we describe further in Box 1, the drawdown of deposits leads to a reduction in reserves in all scenarios other than Scenario 0, where reserves are unaffected. Thus, the central bank may need to restore or generate additional reserves in these scenarios, unless the system holds excess reserves and the central bank wants to accommodate the decrease in reserves (we consider this case in Scenario 1).

The central bank can generate the additional reserves that is needed by the system to purchase the CBDC in several ways, all of which involve an increase in its own assets, such as additional central bank lending or the purchase of bonds. These reserves-generating transactions then neutralize the reduction in reserves

[15] Demand for CBDC is endogenous and depends on factors including (1) efficiency of the existing payment system, (2) remuneration rate, (3) switching cost between other methods of payments. However, for simplicity, we set CBDC demand based on the empirical analysis studied by Li (2022). A more detailed description is explained in Annex I. Such estimates are also provided by Gross and Letizia (2023).

arising from the economy now holding its claims on the central bank in the form of CBDC. These different possibilities also have different implications for how the banking system ends up compensating for the drop in deposits observed on its balance sheet, potentially including increased borrowing from the central bank, or increased borrowing from other sources, such as domestic non-banks or foreign banks.

Moreover, when moving from one scenario to the next, the amount of CBDC demanded (and the amount of deposits withdrawn) increases, assuming a greater appetite by households and firms to hold CBDC, and accordingly larger transactions on the part of the central bank to generate the required reserves. When creating these scenarios, we only make three reasonable assumptions: (1) central banks issue CBDC against other central bank liabilities (either cash or reserves), (2) there is positive demand for CBDC, and (3) issuance of CBDC occurs through the banking system.

Which of the scenarios materializes depends not only on the volume of the CBDC demanded, but also on preconditions, including the amount of cash and deposits in the system, the quantity of excess reserves, and the reserve-offset mechanisms considered by the central bank. Specifically, in countries where cash is predominant—as observed in certain African and Caribbean countries—issuance of CBDC may primarily result in a draining of cash, so that Scenario 0 is likely to materialize. In economies where cash is less common, and the substitution is therefore with bank deposits rather than cash, issuance of the CBDC will primarily lead to a reduction of deposits – as considered in all other scenarios. This then results primarily in a draining of reserves, aligning with Scenario 1, in countries where the banking system holds an excess amount of reserves with the central bank— such as in several advanced economies that have engaged in quantitative easing after the global financial crisis (GFC). In the absence of excess reserves within the banking sector, the central bank is required to counterbalance this reduction, leading to progressively stronger effects on the financial system in Scenarios 2, 3, and 4.

In all scenarios we assume that the net sum of assets in the domestic economy remains unaltered, meaning that CBDC does not create any new “net wealth”. The assumed constancy of “net wealth” also means that CBDC is not being introduced in the economy by way of a “helicopter drop”, but rather is issued in exchange for an existing asset, in practice either cash or commercial bank reserves held with the central bank.

Box 1. Changes in Balance Sheets Following CBDC Issuance Through Reserves and Open Market Operations

This box discusses the consequences of central bank issuance of CBDC for the banking sector and the central bank's balance sheets.

It is important to recall that the total amount of reserves in the banking system is determined exclusively by transactions with the central bank. For example, when Bank A purchases bonds from Bank B and pays with reserves, the total amount of reserves in the banking sector remains unchanged since reserves are simply transferred from Bank A to Bank B. A change in total reserves at the level of the banking sector can only happen following open market operations by the central bank, or changes in autonomous factors such as the issuance of banknotes or changes in government deposits (see, for example, Veyrune et al. (2019)).

Especially, when households increase their cash holdings by withdrawing deposits, the amount of reserves declines because banks use reserves to purchase banknotes. The effect is similar when households purchase CBDC by reducing deposits, since CBDC is also a direct liability of the central bank. The changes in the balance sheets of the central bank and of the banks are summarized in Table A-1.

Table A-1. Changes in balance sheet in the issuance of CBDC

	• Assets	• Liabilities
• Central bank (CB)		• Reserves ↓ • CBDC ↑
• Banks	• Reserves ↓	• Deposits ↓
• Households (HH)	• Deposits ↓ • CBDC ↑	

The issuance of the CBDC leads to a reduction in the amount of reserves banks hold with the central bank. This means that – all else equal – banks' demand for reserves rises, putting upward pressure on interbank rates. In particular, banks may demand more reserves to satisfy reserve requirements if their holdings were close to these requirements prior to the introduction of CBDC. Unless the central bank adjusts the reserve requirement, or operates a floor system (where it supplies abundant reserves at its desired interest rate), it is likely to use open market operations to increase the supply of reserves in response to banks' higher demand for reserves. Open market operations can be temporary or permanent. Temporary operations include central bank lending guaranteed by collateral, in which banks repay the loan after a certain period. Permanent operations include asset purchases, such as government bonds, and imply a permanent increase in the total amount of reserves. The balance sheet changes following the temporary and permanent central bank's operations are summarized in Table A-2 and A-3, respectively.

Table A-2 presents the aggregate balance sheet changes when reserves are generated through central bank lending, corresponding to Scenario 2-A. The size of the banking sector's balance sheet does not change, while the size of the central bank's balance sheet expands due to the issuance of CBDC.

Box 1. Changes in Balance Sheets Following CBDC Issuance Through Reserves and Open Market Operations (concluded)

Table A-2. Changes in balance sheet following the issuance of CBDC (CB lending case)

	• Assets	• Liabilities
• CB	• CB lending ⬆	• CBDC ⬆
• Banks		• Deposits ⬇ • CB lending ⬆
• HH	• Deposits ⬇ • CBDC ⬆	

In the case of central bank asset purchase operations, banks sell their government bonds to the central bank. If banks do not hold enough government bonds, it is NBFIs instead that sell government bonds to the central bank, and then lend the additional reserves to the commercial banking sector. Specifically, in the first step, NBFIs holding reserve accounts sell government bonds to the central bank and increase the reserve holdings, as described in Table A-3, in purple.[1] In the second step, NBFIs lend these additional reserves to the commercial banking sector via wholesale funding, as highlighted in green.

Table A-3. Changes in balance sheet when NBFI sell government bonds to the central bank and increase the wholesale funding

	• Assets	• Liabilities
• CB	• GB ⬆	• Reserves ⬆
• Banks	• Reserves ⬆	• Wholesale funding ⬆
• NBFI	• GB ⬇ • Reserves ⬆ • Reserves ⬇ • Wholesale lending ⬆	

[1] Typically, large investment banks hold reserve accounts with the central bank in advanced economies. However, the overall balance sheet change in this scenario also holds even if NBFIs do not have reserve accounts. For example, when pension funds want to sell their government bonds to the central bank, they can settle this transaction through custodian banks that hold a reserve account.

Summary of Each Scenario

In **Scenario 0**, the distribution of the CBDC involves an exchange for cash, and the CBDC is assumed to have attributes that make it a close substitute of cash. Since such a CBDC mainly drains cash from the economy, the impact on deposits is very limited. This scenario is relevant for economies where cash use predominates.

In **Scenario 1**, the CBDC replaces deposits, rather than cash in households' balance sheets, but banks are assumed to possess excess reserves. When households demand the CBDC, the commercial banking system draws down its existing excess reserves in exchange for the central bank supplying the CBDC,

which is handed out to the household in exchange for deposits. As a result of these transactions, both deposits and reserves shrink in equal measure, and there is no need for additional funding to replace the deposits.

In **Scenario 2-A**, we assume that banks only hold required reserves and that this requirement is not changed by the central bank when it issues the CBDC. However, banks hold sufficient government bonds as liquid assets that can be pledged with the central bank to obtain the additional reserves needed for the purchase of the CBDC on loan from the central bank in a standard open market operation. When this funding is provided, the amount of loans to households and firms that can be offered by the banking system can initially stay the same.

In **Scenario 2-B**, CBDC replaces deposits to a greater extent than in Scenario 2-A, due to an attractive design of the CBDC, such as a positive interest rate. However, banks do not hold sufficient amounts of government bonds to access central bank lending or other central bank market operations to the extent that would be required to generate the necessary reserves. Banks therefore first increase their wholesale funding from NBFI to purchase government bonds from the NBFI sector, and then use these bonds as collateral when they borrow reserves from the central bank. Thus, commercial banks' balance sheets expand, even as the amount of loans the banking system makes to households and firms initially stays the same.

In **Scenario 3-A**, rather than transacting with commercial banks to generate additional reserves, the central bank purchases additional government securities from the NBFI sector. This generates an inflow of reserves into the banking system in exchange for an increase in wholesale funding sourced from the NBFI sector. This increase in wholesale funding replaces the lost deposit funding, keeping the size of commercial banks' balance sheets unchanged.[16] Wholesale funding is assumed to be offered by NBFIs, since all banks in the system face a fall in deposits and reserves and do not have resources to offer funding to each other.

In **Scenario 3-B**, domestic NBFIs are not willing or able to provide wholesale funding to the banking sector, or to sell their government bond holding to the central bank. As a result, banks rely on foreign borrowing, in the form of short-term funding, while the central bank purchases foreign government bonds, rather than domestic ones. Again, these transactions leave the overall size of the domestic banking system unchanged.

In **Scenario 4-A**, we allow second-round effects after the initial set of transactions that are required for the issuance of the CBDC to take place. The starting point here is that the transactions described in Scenarios 2 and 3 result in higher funding costs on a substantial part of the commercial banks' balance sheets, either in the form of additional central bank funding or in the form of additional wholesale funding (domestic or foreign). In this scenario, we assume that banks partially pass on the increase in funding costs to higher loan rates. This reduces loans made to households and firms, compared to the baseline and all previous scenarios.

In **Scenario 4-B**, we allow for an additional second-round effect, by assuming that the commercial banking system tries to stem the deposit outflow by increasing the remuneration of deposits. The banking system does this to avoid having to substitute the lost deposit funding with more costly and less stable wholesale funding. While this could lead to some decrease in the uptake of the CBDC, in the example we assume that the CBDC is still issued and used by households as intended by the central bank. However, banks competitive response leads in equilibrium to increases in funding costs across the whole deposit base, in

[16] In this scenario, NBFIs sell government bonds to central banks to offset the reduction in total amount of reserves. The details of the balance sheet changes in financial institutions as well as in the central bank are described in Box 1.

addition to rises in costs necessary to plug the outflow into CBDC. This results in stronger adverse impacts on loans than in Scenario 4-A.

Table 2 shows the key differentiating features of each scenario: (1) whether CBDC replaces cash or deposits, (2) whether excess reserves are sufficient, (3) how the banks offset the drawdown in reserves, if any, and (4) whether second-round effects are considered, following the initial set of transactions that generate the CBDC.[17]

This table highlights factors which matter for the central bank's and commercial banks' balance sheets, including the offsetting mechanisms that is chosen when CBDC replaces deposits, and reserves held by the banking sector fall. This can simply be a reduction of what had been ample excess reserves. However, if banks do not hold a sufficient excess reserves, the reduction in reserves is offset by an additional transaction with the central bank (e.g., additional borrowing from the central bank) that replenishes the reserves.

In Scenarios 0, 1, 2 and 3, we focus on how the banking sector and the central bank compensate for the initial decrease in either cash or deposits in their balance sheets. In other words, these scenarios correspond to first-round effects. One aspect that is common across these scenarios is that the amount of loans offered by the banking system remains unchanged.

This contrasts with Scenario 4, where we consider second round-effects that arise after the initial set of transactions, as commercial banks begin to change deposit and lending rates in response to the issuance of CBDC. In this analysis, it is these second-round effects only that lead to a shrinkage of the commercial banking system's loans to the real economy.

We next provide a summary of the changes that occur on the balance sheet of the central bank from the introduction of the CBDC across the scenarios. We then highlight the impact on the commercial banking system of those adjustments.

[17] Effects for banking sector balance sheets from private digital money differ from those of CBDC. First, tokenized deposits issued by the banking system do not lead to deposit outflows or changes in reserves. Second, when stablecoins are privately issued by NBFIs, effects on banks depends on what kind of assets the stablecoin issuer holds to back the issuance. If regulation requires full backing with central bank reserves, then the impact on the banking systems is similar to what happens with a CBDC, since this leads to an increase in the reserves the banking system needs to maintain with the central bank. When a stablecoin issuer instead purchases assets from NBFIs the amount of bank deposits or reserves held with the central bank do not materially change, although banks would hold more wholesale- than retail deposits as a result. See Liao and Caramichael (2022) for more detailed discussion of how the financial stability implications vary depending on the type of the assets held by stablecoin issuers. See also Bank of England (2023) for proposals on the regulatory framework for systemic payment systems using stablecoins and related service providers.

Table 2. Key Features in Each Scenario

	CBDC Replacement	Volume of deposit outflow	Excess reserves	Reserve offset mechanism	Second round effects
Scenario 0	Cash	Zero			No
Scenario 1	Deposits	Small	Sufficient		No
Scenario 2-A	Deposits	Medium	Insufficient	CB lending	No
Scenario 2-B	Deposits	Large	Insufficient	CB lending (balance sheet expansion)	No
Scenario 3-A	Deposits	Large	Insufficient	Domestic borrowing	No
Scenario 3-B	Deposits	Large	Insufficient	Foreign borrowing	No
Scenario 4-A	Deposits	Large	Insufficient	Loan shrinks, CB lending	Yes (lending rates)
Scenario 4-B	Deposits	Large	Insufficient	Loan shrinks, CB lending	Yes (deposits and lending rates)

SOURCE: Authors.

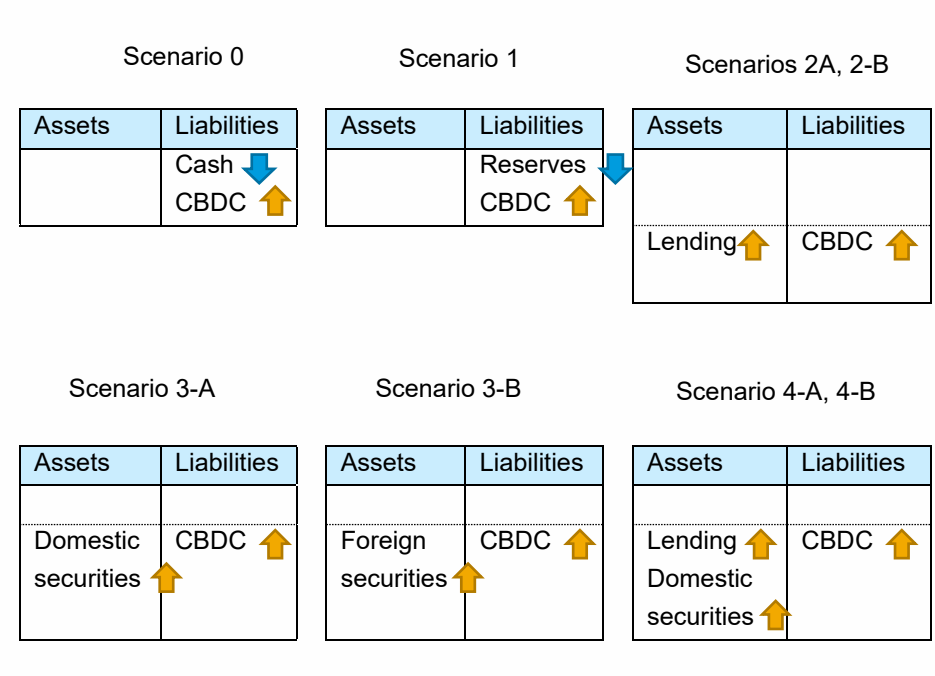
Changes in the Central Bank Balance Sheet

Across the various scenarios changes in the central bank's balance sheet differ (Table 3). From the central bank's perspective, since its liabilities increase with the issuance of CBDC, it needs to either expand its assets or shrink its other liabilities. In Scenario 0, households replace CBDC with cash, implying a switch between CBDC and cash on the liability side of the central bank. In Scenario 1, the central bank allows a reduction in reserves banks hold on deposits, since commercial banks are assumed to have excess reserves. In both these scenarios (i.e., Scenarios 0 and 1), the central bank allows a reduction of other liabilities as the CBDC is issued, thereby holding constant the overall size of its balance sheet.

In stark contrast, the central bank increases its assets to accommodate the growth in its liabilities in Scenarios 2, 3, and 4, thereby expanding its balance sheet, as depicted in Table 3. The central bank has two options to achieve this: it can boost its lending to the commercial banks, as in Scenarios 2-A and 2-B, or it can ramp up its holdings of securities, as in Scenarios 3-A and 3-B. In Scenario 3-B, it increases domestic securities, while holdings of foreign securities are expanded in Scenario 3-C. The central bank is assumed to increase both its lending and securities holdings in Scenario 4. Note that the central bank controls what type of asset holdings it chooses to expand in Scenarios 2, 3, and 4, as highlighted in Table 3.

Overall, this analysis shows that there are two very different outcomes, depending on whether the size of the central bank's balance sheet stays the same (in Scenarios 0 and 1) or whether there is an expansion of the central bank assets, as its liabilities increase. In scenarios where the rise in liabilities leads to an increase in assets, the central bank can either purchase additional assets, or it can provide additional loans to the banking system. Across all these scenarios (Scenarios 2 through 4), the expansion of the central bank's balance sheet is necessary to provide additional reserves to the banking system that allow banks to purchase the CBDC from the central bank on behalf of their customers.

Table 3. Changes in Central Bank Balance Sheet Due to CBDC Issuance



SOURCE: Authors.

NOTE: These tables summarize the change in central bank balance sheet across various scenarios following CBDC issuance. In Scenarios 0 and 1, the central bank decreases its other liabilities when issuing CBDC, while it increases its assets in Scenarios 2, 3, and 4.

Tracking Impacts on the Banking System

The commercial banking system adjusts to the choices made by the central bank by initiating corresponding changes to its liabilities as needed, other than in Scenario 0, which leaves the commercial bank balance sheets unaffected.

To track the impact of these changes, we compute three prudential indicators: the Basel III Leverage Ratio (LR), the Liquidity Coverage Ratio (LCR), and the Net Stable Funding Ratio (NSFR), as well as the net interest margin (NIM) and return on equity (ROE) as measures of the banking system's profitability. Box 2 provides details on how we compute these indicators. Table 4 shows the effects on the prudential and profitability metrics that result from each scenario. The specific balance sheets we use to calculate these ratios are shown in Annex 1, and the impacts of the scenarios are described in more detail below.

Under both Scenario 0 and Scenario 1, there is no, or virtually no impact, on prudential and profitability metrics (Table 4). In these scenarios, one central bank liability is exchanged for another and there is very little, if any, effect on the banking system from these transactions. It is worth noting that in Scenario 1 this is the case despite the drain in deposits. The reason is that this drain is accommodated on the asset side of the balance sheet by a reduction of reserves, assumed to be ample.

Table 4. Prudential Ratios, NIM, ROE, and Loans in Each Scenario

	Baseline	Scenario 0	Scenario 1	Scenario 2-A	Scenario 2-B	Scenario 3-A	Scenario 3-B	Scenario 4-A	Scenario 4-B
LR	0.050	0.050	0.050	0.050	0.048	0.050	0.050	0.051	0.053
LCR	1.40	1.40	1.39	0.65	0.57	1.12	0.90	0.44	0.70
NSFR	1.09	1.09	1.09	0.98	0.92	0.95	0.92	0.95	0.99
NIM	0.0278	0.0278	0.0275	0.0264	0.0248	0.0243	0.0256	0.0273	0.0256
ROE	0.087	0.087	0.084	0.053	0.043	0.009	0.033	0.055	0.010
ΔLoans		0	0	0	0	0	0	-4%	-8%

SOURCE: IMF staff estimates.

Impacts on prudential ratios only emerge in scenarios where the central bank expands its balance sheet (Scenarios 2 and 3). In these scenarios, liquidity metrics worsen, and the LCR and the NSFR fall below their regulatory minima in some of these scenarios, including in Scenarios 2-A, 2-B and 3-B. This is due to an increase in short-term funding and the reduction in deposit funding, which is treated as long-term in these calculations. Scenario 2-A also sees an impact on the LR as commercial banks expand their balances sheets to obtain additional government bonds for use as collateral in open market operations with the central bank.

Moreover, across Scenarios 2 and 3, profitability, as measured by the ROE or NIM, is under pressure since banks need to replace deposits – the cheapest funding source – by other funding sources, either central bank funding, wholesale funding, or both. However, in Scenarios 2 and 3, we keep the loan portfolio unchanged, so that all adjustments apply initially to liquidity metrics and profitability.

In Scenario 4, second-round effects lead to changes in the provision of loans to the economy. In Scenario 4-A we assume that banks pass on some of the increase in funding costs to loan rates. The provision of loans contracts in response to the higher interest rates charged by the banking system. In Scenario 4-B, there is an additional competitive effect, where banks try to keep deposits from flowing towards the CBDC by increasing the remuneration of deposits. Higher funding costs then arise not only from an increase in wholesale funding, but also from a rise in the interest paid on banks' entire deposit base. Some of the increase in costs is reflected in a further drop in profits. In addition, there is a stronger fall in the provision of loans. Compared to Scenario 4-A the amount of lending falls more because the higher overall funding costs shift the loan supply curve of the banking system further back, which then meets loan demand at a reduced volume.

When considering such second-round effects, it is again worth emphasizing the importance of preconditions. In all scenarios other than 0, we consider a starting point where the bulk of payments made by households and firms are deposit based, for instance using debit and credit cards, and households do no hold any material amounts of cash. In all these scenarios, we therefore assume that deposits drop by the same amount as the volume of CBDC issued.

In intermediate situations, where households still also hold substantial amounts of cash, there could be a flow from both cash and deposits into the CBDC, reducing the initial impact on banks. Moreover, additional effects that have been emphasized by parts of the literature are conceivable (Andolfatto 2021, Chiu et al. 2023, Chang et al. 2023). In particular, an increase in the remuneration of deposits (as discussed in Scenario 4-B)

could succeed in getting households to switch from cash to deposits, thereby generating a deposit rise that may partially offset the initial outflow of deposits. We explore further the range of outcomes for financial stability in the next section.

Box 2. Prudential Ratios and Profitability Indicators

The scenario analysis tracks the effects of the introduction of the CBDC on three regulatory metrics: LR, LCR, and NSFR, which are all part of the Basel III framework, as well as the impact on banks' profitability. The regulatory metrics considered here (LR, LCR, and NSFR) aim to limit and manage risks from increases in leverage and volatile wholesale funding that had emerged ahead of the GFC. We also consider a measure of bank profitability to track the incentive for banks to change their behavior in response to the CBDC.

The Leverage Ratio

LR was introduced in the wake of the GFC to contain the build-up of balance sheet leverage in the banking sector that could occur even when banks are subject to risk-weighted capital requirements.[1] We use a simple definition of LR that is sufficient to capture the key aspects of the stylized balance sheets considered here:[2]

$$LR = \frac{High\text{-}quality\ capital}{Total\ non\text{-}risk\text{-}weighted\ assets}.$$

In our baseline scenario, the actual LR is 5 percent, just above the Basel III minimum requirement of 3 percent. Variations in this measure across the scenarios can come about as the balance sheet of the commercial banking sector expands or contracts due the issuance of the CBDC.

The Liquidity Coverage Ratio

The LCR was introduced to force banks to hold sufficient highly liquid assets as insurance against cash outflows. Based on the Basel III definition, the LCR is calculated as:

$$LCR = \frac{HQLA}{Total\ net\ cash\ outflows} = \frac{(Gvt\ bonds - CB\ lending) + Reserves + 20\% \times Other\ assets}{5\% \times Deposits + 50\% \times Other\ ST\ liabilities}.$$

where the denominator represents the total net cash outflows over the next 30 days, while the numerator is the stock of high-quality liquid assets (HQLA) to cover these outflows. In the numerator, the government bonds must be unencumbered, and therefore exclude sovereign bonds already used by banks as collateral for borrowing from the central bank (assuming zero haircuts, the volume of collateral is equal to the amount of central bank lending). 20 percent of the other assets are considered as HQLA (including high-rated corporate debt and mortgage-backed securities).[3] In the denominator, only 5 percent of deposits are assumed to be flighty,[4] and 50 percent of the other short-term liabilities are assumed to be cash outflow items, that is, liabilities of less than 30 days. Existing debt is assumed to be long-term and therefore does not require HQLA under the LCR calculations.

[1] See BIS (2014a) for an overview.

[2] The Basel III definition of the exposure measure (the denominator) includes derivative exposures, securities financing transaction exposures, and off-balance sheet items, but for simplicity, our scenario analysis is limited to on-balance sheet exposure.

[3] According to BIS (2013), corporate debt securities rated AA- or higher could be considered as HQLA with a factor of 85 percent and residential mortgage-backed securities with a factor of 75 percent. Thus, we assume that Other assets are a composite of corporate debt and mortgage-backed securities, and others not qualified as HQLA. 20 percent of other assets are assumed to be used as HQLA, overall, so that LCR is above the regulatory requirements in the baseline balance sheet.

[4] This is based on the factor described in Annex 4 in BIS (2013), in which 5 percent of total amount of stable retail deposits should be considered as cash outflows when calculating LCR.

Box 2. Prudential Ratios and Profitability Indicators (concluded)

The Net Stable Funding Ratio

NSFR complements the LCR by more directly limiting banks' reliance on potentially more volatile wholesale funding. Based on the Basel III definition,5 the NSFR is:

$$NSFR = \frac{Available\ amount\ of\ stable\ funding}{Required\ amount\ of\ stable\ funding} = \frac{95\% \times Deposits + 30\% \times Debt\ issued + Capital}{Loan + 30\% \times Other\ assets},$$

where 95 percent of retail deposits are assumed to be stable, 30 percent of the debt issued has a maturity above 1 year, while central bank lending and other short-term liabilities have a maturity below 6 months and are therefore not included in the computation of the NSFR. On the asset side, all the loans are encumbered for a period of one or more years, the government bonds are safe (and therefore do not appear in the denominator of the NSFR), while 30 percent of the other assets are assumed to be of lower quality with a long-term maturity.

Profitability

The profitability of the banking sector is not, in and of itself, a central bank policy objective, nor does a reduction in profit necessarily have adverse financial stability implications. However, an increase in funding costs, such as from a rise in wholesale funding, can transmit to higher lending rates and lead to a reduction in the provision of credit to the economy, all else equal. Moreover, an unprofitable banking sector will see its capital erode over time, leading to incentives to take risks when capital becomes thin and leverage high. These issues are discussed in more detail in the next section and motivate us to track an indicator of profitability through our scenarios.

The profitability of the banking sector is measured by the ROE, calculated as:

$$ROE = (NIM \times Total\ Assets + Other\ Revenues - Other\ Expenses\ )/Capital,$$

where *NIM* is the net interest margin of the consolidated banking sector, defined as:

$$\begin{aligned} NIM &= (Investment\ income - Interest\ expenses)/(Total\ Assets) \\ &= (5\% \times Loan + 3\% \times GB - 0.1\% \times Deposits - 2\% \times CB\ lending - 4\% \times Debt\ issued \\ &\qquad - 2\% \times Other\ ST)/(Total\ Assets), \end{aligned}$$

with values of the various interest rates (on loans, deposits, CB lending…) being based on euro area and United States (US) data.

In the baseline scenario, the values of *Other Revenues* and of *Other Expenses* are such that the ROE is around 9 percent.[6] The issuance of CBDC will weigh on the profitability of the banking sector through the NIM, but also through the *Other Revenues* and *Other Expenses*. For example, a drop in deposits will reduce the services usually charged by banks on those deposits, while according to Stiroh (2004), charges related to these services represent roughly 5–6 percent of total revenues. In response to the issuance of CBDC, we assume that the services charges, accounting for 5 percent of the entire revenues, decline in proportion of the drop of deposits.[7]

[5] See BIS (2014b) for an overview.

[6] Based on Stiroh (2004), the value for Other Revenues is set at 185, representing 40 percent of the entire revenue. Other Expenses are assumed to be 420, implying an ROE of around 9 percent. For comparison, the ROEs of the euro area and the US banks have been around 5 and 10 percent since the GFC, respectively, according to European Central Bank (ECB) data and Federal Reserve Economic Data (FRED).

[7] However, the drop in service charges could potentially be offset if banks themselves offer CBDC services.

To complement this analysis, we provide a more comprehensive discussion of financial stability implications beyond the initial impacts considered in the scenarios in the next section. We also provide cross-country data on the factors affecting the likelihood of the realization of the initial impact scenarios in Annex 2.

4. Potential Implications for Financial Stability

This section discusses further the ensuing financial stability implications of CBDC introduction, taking the initial scenario outcomes described in the previous section as a starting point. Potential implications include the following:

(1) A large substitution of CBDC for deposits can make it more difficult for banks to adhere to key prudential constraints, such as the LCR, NSFR, and the LR, unless excess reserves are ample.

(2) Increased competition for deposits and replacement of low-cost deposit funding with central bank- or wholesale funding reduces banks' profits. Some banks may respond to profitability pressures by increasing risks on their balance sheets, and others may exit the market or choose to consolidate.

(3) If banks lose deposit funding, they are likely to increase the share of wholesale funding, strengthening the interconnections with NBFIs. As wholesale funding replaces deposits in banks' liabilities and the cost of funds becomes more exposed to exogenous shocks, banks' lending rates may become more volatile. Banks' tighter links to NBFIs would make the financial system more exposed to funding shocks that could disrupt the provision of finance to the real economy. Moreover, if banks started relying on foreign-currency funding from foreign financial institutions, they would need to manage the associated Foreign Exchange (FX) risk.

(4) If banks replace their deposit funding by borrowing from central banks, banks' demand for sovereign bonds may rise because central bank loans are typically collateralized with HQLA. As a result, the sovereign-banks nexus may become more entrenched.

(5) Banks may reduce credit provision to the private sector. If funding costs increase due to a drop in deposits, banks may find some loans or investment projects no longer profitable, cutting credit provision. More rapid structural changes may also be observed, as a result of multiple equilibria and network effects in the adoption of new monies, and when customers fully turn away from using banks for savings purposes.

(6) Financial stability risks are likely most pronounced during stress times. When the CBDC is widely accessible and seen as a "safe haven" asset, periods of stress can generate an increased risk of runs from individual banks, or the banking system as a whole, into the CBDC. Such runs are likely to be more concerning in the presence of a tail of weaker banks. These banks may experience much greater disintermediation pressures in stress conditions, and face difficulties in replacing retail deposits with wholesale funding.

Some of the financial stability implications we draw out differ depending on the scenarios realized, while others are common to all scenarios, as Table 5 summarizes. This table also highlights the relevant financial stability implications of each scenario.

One key driver of the effects discussed here is the size of the drain on deposits relative to total assets, with most effects increasing in severity the larger is the deposit outflow. However, the financial stability effects are also conditional on other important factors, including the existing holdings of reserves, the availability of other HQLA to support borrowing from the central bank, the existence of other domestic funding sources, as well as the competitive environment within the banking system.

Table 5. Key Effects of CBDC Across Scenarios

	CBDC replacement	Excess reserves	Reserve offset mechanism	Second round effects	Financial stability implications
Scenario 0	Cash			No	Limited impacts
Scenario 1	Deposits	Sufficient		No	Limited impacts
Scenario 2-A	Deposits	Insufficient	CB lending	No	1. LCR, NSFR 2. Profits decline
Scenario 2-B	Deposits	Insufficient	CB lending (balance sheet expansion)	No	1. LCR, NSFR, LR 2. Profits decline 3. NBFI funding 4. SB Nexus
Scenario 3-A	Deposits	Insufficient	Domestic borrowing	No	1. LCR, NSFR 2. Profits decline 3. NBFI funding 4. SB Nexus
Scenario 3-B	Deposits	Insufficient	Foreign borrowing	No	1. LCR, NSFR 2. Profits decline 3. NBFI funding 4. SB Nexus
Scenario 4-A	Deposits	Insufficient	Loan shrinks, CB lending	Yes (lending rates)	1. LCR, NSFR 2. Profits decline 5. Credit contraction
Scenario 4-B	Deposits	Insufficient	Loan shrinks, CB lending	Yes (deposits and lending rates)	1. LCR, NSFR 2. Profits decline 5. Credit contraction

SOURCE: Authors.

NOTE: SB stands for sovereign-bank.

Unless the issuance of CBDC leads mainly to a reduction in cash, rather than deposits, in a financial inclusion scenario, and unless reserves are more than ample to allow the purchase of the CBDC, the CBDC may result in some decline in credit provided to the real economy, but the magnitude of this effect is quite uncertain. In addition, the impact on financial stability depends on the pace with which a move to a new regime with a CBDC takes place, and to what extent the system is under normal conditions, or in a crisis mode, as we point out below.

Breach of Prudential Ratios

In several scenarios, the introduction of a CBDC causes banks to breach prudential constraints, such as the LCR, the NSFR, and potentially the LR. The LCR and NSFR will be lower when in the face of deposit outflows, banks need to rely on short-term funding such as central bank lending and wholesale funding. This is because deposits are considered as a stable funding source, with lower implicit risk weighting in the calculation of the LCR and the NSFR, while other funding is considered more risky. In addition, when commercial banks increase central bank borrowing, they need to pledge additional collateral, which then lowers the HQLA used to calculate the LCR, since assets count towards HQLAs only when they are unencumbered. Thus, if a significant share of deposits is replaced, some banks may not be able to maintain the regulatory LCR and NSFR minima. Moreover, the LR can fall (implying higher leverage), as seen in Scenario 2-B, where banks increase wholesale funding to purchase government bonds, which is then used as collateral. When commercial banks are close to the minimum requirement in the LR to begin with, this scenario can lead to a breach in this requirement.

In principle, banks can adjust to regain compliance with the prudential ratios. And while several options are feasible, they will typically involve a further drop in bank profitability or bank lending. The first option is to raise longer-term funding (longer than 30 days for LCR and longer than at least 6 months and ideally 1 year for NSFR).[18] However, this would increase the funding costs of banks, reducing their profitability. A second option is to boost the share of HQLA, for example, by reducing loans or other risky investments. This would increase the LCR or NSFR but will again also weigh on profits and loans provided.

Banks could finally respond to the introduction of CBDC by raising the remuneration of deposits, thereby limiting deposit outflows. If successful, this would help maintain the prudential ratios and reduce the need to resort to central bank or wholesale funding. Under such a response, moreover, the amount of CBDC held by households could be more limited in equilibrium. However, the effect on bank profitability of this response is again likely to be negative, since in either case the cost of funding increases, implying a risk of increased risk-taking or of exit of parts of the system (as explored further below).

Reduction in Profits and Greater Banks' Risk Taking

As discussed earlier, competitive reactions to the introduction of the CBDC could lead to an increase in rates paid on the remaining deposit base (see also Mancini-Griffoli et al. (2018)). The heightened costs would adversely affect banks' profits and cause the bank franchise values to decline.[19]

A large literature draws out how increased competition can affect the behavior of banks. Keeley (1990) explains how deregulation in the US in the 70s and 80s increased competition and lead to lower the banks' charter value, and to more risk taking by banks. Allen and Gale (2004) study a suite of models to understand the connection between competition and financial stability, and a survey of the effects is in IMF (2013). This literature suggests that there are four channels through which the introduction of a CBDC can affect competition among banks.

First, the existing level of competition in the banking system matters for the effects of a CBDC on bank profits and lending. When banks have access to both deposit and wholesale funding, they have the option to

[18] When the maturity of liability item is larger than 6 months, this will increase the NSFR.

[19] Andolfatto (2021) studies the introduction of a CBDC in an overlapping generations model with monopolistic banks. While the introduction of CBDC does not affect bank lending activity, it does reduce bank profit as banks raise deposit rates to attract deposit funding.

substitute deposits with more costly wholesale funding. While this unambiguously drives up banks operating costs, the effects on profits and bank lending depend on the degree to which banks are able to pass on their increased costs. In less competitive systems, in which banks enjoy monopoly rents, banks will likely absorb some of the increased cost and the effect on loans provided is less pronounced. By contrast, where lending markets are nearly perfectly competitive, and economic profits therefore already near-zero, basic theory predicts that all of the increase in costs will be passed into higher lending rates, then ultimately leading to a stronger reduction in provision of credit to the real economy.

Second, when banks' cost of funding increases, banks may respond by increased risk taking. Such an effect is known in the literature as "risk-shifting", since rises in risk shifts value away from debtholders and towards bank shareholders. As explained by Dell'Ariccia et al. (2014, 2016), the strength of this effect depends on the banks' capital structure. The incentive to take on more risk is stronger for more leveraged banks, and weaker for better capitalized banks. Moreover, according to the seminal study by Keeley (1990) incentives to take risk will be smaller the larger the remaining "franchise value" of the bank that shareholders stand to lose when they increase risk.[20, 21] Cross-sectionally, the risk-shifting effects could therefore arise for the least well-capitalized and least profitable banks, while better capitalized banks may have weaker incentives to take risk. Risk-shifting incentives could also strengthen over time, when reduced profitability leads to a slow erosion of capital positions.

Third, competition can be affected by the effect of the CBDC on informational frictions in loan markets. If deposit outflows lead to a reduction in banks' access to information on customers, this can result in poorer decision making by banks, increasing credit risk and reducing the amount of credit banks want to provide. However, some of these effects could be offset if banks' role in the distribution of CBDC services would allow them to retain information on payments made using the CBDC. Depending on the design of the CBDC, the information available to participating banks could even increase, such as when all participating banks on the payment platform on which the CBDC circulates are given access to information on all transactions. In such a scenario, there could be an increase in competition in loan markets, as client information on transactions is no longer private to each bank but available to competitors. These effects depend strongly on the way the platform is designed (see Box 3).

Finally, the decline in profitability may lead some banks to exit or to be taken over, resulting in a consolidation of the market. For instance, Chiu et al. (2023) find that the introduction of a CBDC lowers banks' profits, and hence leads to a lower number of active banks. This prospect is more likely if the banking system is struggling with profitability even without the CBDC. A consolidation could even be seen as a welcome in markets where profitability has been structurally weak for some time.[22]

However, in the process of consolidation, banks may become larger, and some could become systemically important (or too-big-to-fail). When consolidation leads to a greater number of systemically important banks, it

[20] Adding to this literature, Choi and Rhee (2022) study the introduction of a CBDC in a principal-agent framework. They find that banks are incentivized to take on more risk when deposit holders' value for the CBDC is not extreme (high or low). Chiu et al. (2023) also study the CBDC's impact on banks' risk taking. In their model the impact can go either way, depending on the model's assumptions.

[21] If increased risk-taking is associated with greater risk-weighted assets, it can result in higher capital requirements. However, banks can also increase their risk-taking with neutral effect from a risk-weighted assets perspective (e.g., through increased sovereign exposures or by moving to IRB models), avoiding the need for additional capital.

[22] In principle, consolidation can help banking systems that struggle as a result of too large a number of banks, that is in systems that are "overbanked,"

would be important for them to have sufficient capital to satisfy tighter requirements.[23] While large banks are subject to tighter regulation, the Financial Stability Board (FSB) concluded in its evaluation of the too-big-to-fail reforms that gaps remained in the implementation of resolution reforms and data, while the reforms also appear to have shifted some activities to nonbanks.[24]

Box 3. Impact on Financial Institutions' Access to Information on Borrowers' Credit Quality Depending on Design of CBDC

A fall in deposits following the introduction of CBDC – in all scenarios other than Scenario 0—could alter the amount of information the banks can access, with implications for the functioning of credit markets.

In the absence of a CBDC, clients' payment activities are visible to banks and generate roughly 90 percent of banks' useful customer data according to McKinsey (2019). This information is typically used to inform credit decisions, as documented by several empirical studies, including Puri et al. (2017) using German data on consumers, Mester et al. (2007) using Canadian data on small businesses, and Hau et al. (2019) using data on loans made by Ant Financial to online vendors.

Parlour et al. (2022) discuss the consequences of the disruptions implied by fintech payments for the synergies that banks have between payment and credit. Since banks use payment data to learn about consumers' credit quality, the competition from fintech payment providers affects banks' ability to benefit from this information spillover, ultimately weighing on bank lending. Ghosh et al. (2021) also discuss the importance of these synergies for fintech lenders and present empirical evidence from an Indian fintech company. Thus, the literature suggests that increased competition from CBDC or other non-bank payment methods could be detrimental to banks' credit provision if banks lose sight of consumer payment transactions.

The effect of CBDC on the ability of banks to assess a potential borrower's credit quality depends heavily on the design of CBDC. For instance, banks' role in the distribution of CBDC services could allow them to retain information on payments made by their clients using the CBDC. Depending on design the information available to participating banks could even increase. In particular, when all banks that are participating on the payment platform are given access to information on all CBDC transactions made on it, the available information could increase substantially. In the latter case, one would expect a strong increase in competition in credit markets, as what used to be banks' proprietary information would become available to competitors in loan markets.

However, there might be a trade-off between ensuring credit quality information to the banking sector and customers preference for privacy and the desire to ensure that users can make at least some payments anonymously (see ECB (2022), for example). Providing and constraining access to this information is an important consideration for the design of the CBDC and the underlying legislation on the provision of financial services. Central banks will need to make informed design decisions which strike a balance between the potential adverse effects of constraining access to information and privacy.

[23] See Global systemically important banks: assessment methodology and the additional loss absorbency requirement (bis.org) for the Basel Committee's framework on identifying G-SIBs.

[24] See Evaluation of the effects of too-big-to-fail reforms: Final Report - Financial Stability Board (fsb.org).

Wholesale Funding and Interconnections with NBFIs

The issuance of the CBDC leads to a growth in the share of wholesale funding—typically sourced from NBFIs—in several scenarios. This can be concerning since increased reliance on short-term wholesale funding was one of the key elements that contributed to the GFC in 2007–09, and has resurfaced as a risk again in the context of the COVID-19 pandemic.

The introduction of a CBDC could induce banks to increase their dependence on such NBFI funding. Domestic NBFIs holding safe assets at the time of CBDC issuance may receive liquidity inflows and ultimately lend to banks on the wholesale market, as we explore in Scenarios 2-B and 3-A.[25] This means that the NBFIs would rebalance their portfolios towards the banking sector, which could be in the form of commercial paper, longer-term bank unsecured debt, or collateralized bank debt (e.g., covered bonds). In countries where domestic alternatives to deposit funding are scarce, banks could tap cross-border funding from foreign NBFIs instead, then likely in foreign currency, as we explore in Scenario 3-B.[26, 27] If the share of such funding were to grow large, these changes could affect banks' ability to cope with liquidity problems and to work as a shock absorber.[28] Forbes et al. (2022) study the stress experienced at the onset of the COVID-19 pandemic and find that banks with a higher share of funding from NBFIs or in US dollars experienced higher stress.[29] By substituting their government bonds (sold to central banks) by banks' debt, some NBFIs will also experience an increase in the riskiness of their assets.

If banks respond to increased competition for deposits by increasing their reliance on NBFI funding, the whole financial system could become more exposed to funding shocks, with adverse effects on financing of the real economy. A shock that would trigger large redemptions from the open-ended investment funds could dry up the funding from both non-financial corporations (NFCs) and banks. If large market moves trigger margin calls, other NBFI investors with derivatives exposures may also be forced to liquidate their positions to post more cash collateral, thus being also unable to provide funding for banks or NFCs. The NBFI sector's liquidity position could also become more vulnerable as a result of a CBDC issuance, such as when households opt to redeem shares in open-ended funds and money market funds in favor of the greater safety of CBDC. The CBDC could then add to the flightiness of wholesale funding received by banks.

Additional issues arise if banks increase their reliance on foreign NBFIs.[30] If foreign NBFIs are unwilling or unable to roll-over their funding, it may be very difficult for banks to replace it, especially when the funding is in foreign currency. Banks themselves would therefore need to manage the associated FX and liquidity risks, such as through holding precautionary FX assets and FX derivatives. However, difficulties in rolling over FX funding can also lead to liquidity problems in derivatives markets, as witnessed in the March 2020 "dash-for-cash" episode (see Avdjiev et al. (2020)).

[25] As illustrated in Tables 6 or 8 (see Annex 1), the central bank is purchasing securities (probably only government bonds) in exchange of the liquidity received from deposits. Part of these securities are likely to be sold by NBFIs which will then receive liquidity to be lent on the wholesale market to banks.

[26] We focus on the cases where banks receive funding from cross-border NBFIs. In the simplest case, the central bank buys (government) assets from the foreign NBFIs that use the proceeds to fund the banks.

[27] See He (2024) for a more comprehensive discussion about how a CBDC can affect capital flows.

[28] See also FSB (2020) on the banks' role as a shock absorber in March 2020.

[29] Their measure of stress is based on a change in the banks' CDS spread.

[30] BIS (2020) shows that cross-border links between banks NBFIs grew rapidly since 2015 up until the pandemic.

A large reduction in banks' deposits could also imply more volatile lending, with negative financial stability effects, especially in countries with flexible interest rates on loans. Berlin and Mester (1999) document that banks funded more heavily with core deposits, which are in relatively inelastic supply and therefore insulate banks' cost of funds from exogenous shocks, provide more loan-rate smoothing for their borrowers. The substitution of deposits by wholesale funding following an issuance of a CBDC could increase the volatility of banks' funding costs and thereby of banks' lending rates.

Deepening of the Sovereign-Bank Nexus

In some scenarios, banks replace their deposit funding with funding from central banks. As central bank lending is typically collateralized, banks' demand for high quality collateral to be used in such operations rises. A shift towards central bank funding could then increase banks' holdings of sovereign bonds. Additional holdings of domestic sovereign bonds would not affect banks' risk weighted assets thanks to sovereign bonds zero-risk weight treatment in bank regulation. The replacement of deposits with central bank funding and a related increase in sovereign holdings would, however, exacerbate the sovereign-bank links that have grown since the pandemic (IMF, 2022a), and add to the elevated level of vulnerabilities in some emerging market countries with highly indebted sovereigns.

Dell'Ariccia et. al. (2017) discuss the channels through which banks and sovereigns are connected and consider ways in which regulation could weaken the nexus. IMF (2022a) finds that the nexus has strengthened in emerging markets following the pandemic, as banks increasingly stepped in to purchase government bonds. A further tightening of the sovereign-bank nexus from an increase in banks' exposure to the domestic sovereign can in turn possibly create a doom loop between the fiscal and financial sectors in the event of shocks, and adversely affects banks' balance sheets and lending appetite in countries with weaker bank capitalization or with fiscal vulnerabilities.

A heightened allocation of savings towards funding of government assets, and away from the funding of private sector loans could also induce higher government indebtedness, increasing further the scope for negative feedback loops between macroeconomic shocks, deteriorating fiscal positions, and increased risk from financial exposures to the sovereign. In addition to the strengthening of the sovereign-bank nexus, the higher demand for high-quality collateral could also affect the financial system more broadly, if lower returns on bonds prompt a search-for-yield, potentially increasing the riskiness of the financial system.

Lower Bank Credit Provision to the Public

A reduction in the supply of credit to the real economy can arise from two channels that are highlighted across our scenarios. First, as households and firms switch out of bank deposits into CBDC, banks may lose information that can be gained from deposit relationships, as well as the ability to foreclose on incoming funds in the event of default.[31] This leads to greater risks in lending, thereby pushing up lending rates, and curtailing credit supply. Second, as competition for deposits rises and banks are forced to offer higher rates on deposit

[31] For example, Donaldson et al. (2018) points out that banks have the right to seize the deposits of a defaulting borrower as repayment—a right called banker's setoff, which originated from their earlier warehouse function. A fall in deposits due to the introduction of CBDC could therefore weigh on lending by reducing the enforcement power of banks, even if banks were able to replace deposits by wholesale funding at no additional cost.

funding or replace this funding by more costly wholesale funding, the cost of funding of the banking system rises, and this increase in cost is then passed on to lending rates.

That pass through will occur either fully, if the banking system is competitive, or partially, if bank competition is monopolistic and banks absorb some of the increase in cost by lowering profits. Whatever increase in loan rates occurs will then lead to a reduction in the provision of credit to the economy (see, e.g., Agur et al., 2022).

The effects on lending also depend on the ease with which the banks can substitute deposits with wholesale funding. Larger banks may be better able to do so, putting them at an advantage relative to smaller banks (e.g., Whited et al. (2023). They can finally depend on the degree of financial inclusion that could materialize and lead to some offsetting inflow of deposits (see further Box 4).

The adverse effects on the provision of credit should not be material in scenarios where the size of the central bank balance sheet is unchanged, such as when the CBDC is exchanged one for one with cash or existing excess reserves. By contrast, as explained above (Table 2) where issuance of the CBDC is against deposits and the central bank needs to generate additional reserves for banks to be able to purchase the CBDC on behalf of their customers, the issuance of the CBDC leads ultimately to an increase in the balance sheet of the central bank.

Scenarios entailing an expansion of the balance sheet of the central bank imply an increase in “outside” money— liabilities of the central bank, including physical and digital currency, as well as reserves — potentially to the detriment of the use of “inside money“ — deposits created by banks, that is “inside” the banking system. Such a substitution may then ultimately weigh on the amount of credit provided to the economy, through the mechanisms set out above, and discussed in Scenarios 4-A and 4-B.

Evidence on the extent to which an increase in “outside money” ultimately leads to a reduction in the provision of credit to the economy is still very scarce. A fair number of studies have found that liquidity pressures on banks can reduce their provision of credit to the economy in times of stress (e.g., Peek and Rosengren, 2000, Khwaja and Mian, 2008). However, very few studies have examined the implications of structural changes in payments technology on the provision of credit. One such study assesses the introduction of efficient payment systems in Eastern European countries during the period 1995 to 2005 (Merrouche and Nier, 2012). This study finds that these payment system reforms were associated with a trend decrease in the use of currency, relative to demand deposits. Moreover, these reforms also led to a marked trend increase in credit supplied to the private sector, due to sizable increases in the amount of funds intermediated by the banking system.[32] Another study examines the implications of the granting of a monopoly in the issuance of banknotes to the Bank of Canada from 1935 on the activity of chartered banks (Grodecka-Messi and Zhang, 2023). It finds that barring other banks from issuing such notes reduced their profits, but had no effects on lending, potentially because deposits funding remained available to these banks.

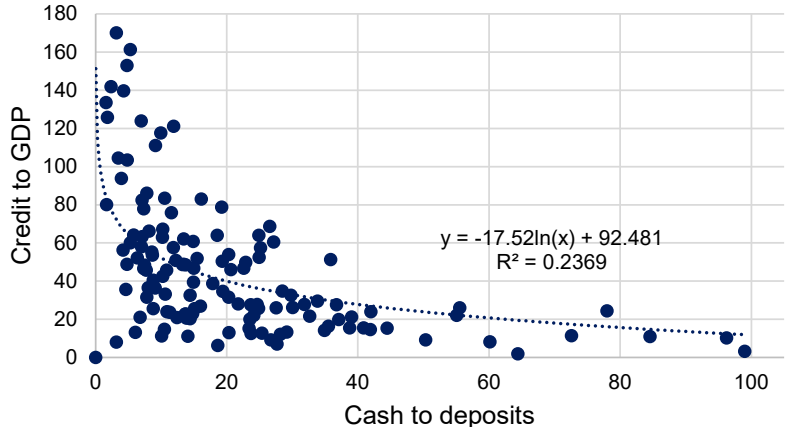
Using aggregate information, we find a clear negative correlation between the ratio of cash to deposits and the amount of credit to the private sector as a share of GDP (Figure 1). While this correlation may not be causal, it could still lend some support to the notion that a greater amount of outside money can be associated,

[32] Furthermore, the trend increase in credit supplied to the private sector seemed to reflect a trend decrease in the use of currency (outside money), relative to demand deposits (inside money), but less so a reduction in banks’ holding of excess reserves (outside money).

all else equal, with a reduced provision of private credit to the economy. It should be noted however, that the introduction of a CBDC alone is unlikely to imply increases in the cash-to-deposit ratios as large as what is reported on Figure 1—where the ratio increases from near zero to near unity, reflecting large differences in that ratio across the range of countries in the sample.[33]

A reduction in the provision of bank credit to the real economy may in part be compensated by an increase in the provision of credit by non-banks. Greater provision of credit by non-banks could become plausible in particular when nonbanks are involved in the distribution of the CBDC and are given access to information on payments made across the system. However, NBFIs do not gain additional sources of funding, because households increase holdings of assets with the central bank, rather than the NBFI sector.[34]

Figure 1. Cash-to-Deposits and Credit-to-GDP Ratios



SOURCES: IMF International Financial Statistics (IFS) and Monetary and Financial Statistics (MFS), and authors' calculations.

NOTE: Scatter plot between the average ratio (2017–21) of cash to deposits (transfer deposits and other deposits) and of banks' credit to the non-financial private sector as a share of GDP for a sample of 131 advanced and emerging market and developing economies.

Where there is an increase in outside money, there may therefore be some increase in the required return on risky loans, all else equal. In the longer run, this could lead to a fall in the share of such loans in total financial assets, and a resulting drop in investment, employment, and potential output (see, e.g., Agur et al., 2022). It could also reduce the ability of households to smooth consumption using bank credit, even as greater efficiency of payments could also improve welfare (Burlon et al., 2022).

[33] Note that the proportion of cash in GDP varies significantly across countries (see Annex Figure 1), without any apparent correlation with the level of economic development or financial intermediation (for instance, Panama barely use cash, similar to Norway and Sweden while at the other end of the spectrum, Japan and Hong Kong show a strong preference for using cash, with a proportion of currency in GDP similar to the one of Iraq or Tajikistan). One reason is that the degree of preference for cash versus deposits can reflect structural factors of the credit card industry not necessarily correlated with the level of economic development. Bagnall et al. (2014) for instance find that the large cross-country differences in the use of cash observed in seven advanced economies (Australia, Austria, Canada, France, Germany, the Netherlands and the United States) reflect differences in the dissemination of credit cards, in the average card transaction value (in card-intensive countries, the average card transaction value is lower than it is in cash-intensive countries), and in the acceptance of payment cards by merchants differs across countries.

[34] We discuss further down a more radical scenario, where households pull all of their funding from banks and put some of this into the CBDC and some into brokerage accounts with NBFIs. This clearly leads to increased funding for the NBFI sector.

The size of the effect on credit may or may not be large, depending on the design of the CBDC, prevailing conditions, and mitigating actions taken. In particular, as illustrated by our scenario analysis, the effects on credit are likely to be mild in economies where the banking system can accommodate the increase in CBDC by drawing down existing reserves with the central bank – limiting the central bank's balance sheet expansion. This is because there is then no need for banks to increase more costly wholesale or central bank funding in response to the issuance of the CBDC.

Increases in funding costs and a reduction in loan volumes could still occur if the CBDC is remunerated, so that competition with the CBDC leads to hikes in rates paid on deposits. A knock-on effect on credit from increases in deposit rates is more likely when households do not carry material amounts of physical cash, limiting the potential for offsetting deposit inflows out of cash.

If material effects were to arise, they could potentially be more concerning for economies where firms rely on bank credit for funding than in countries where the bulk of corporate funding is sourced in capital markets (e.g., Keister and Sanches, 2023). For a brief survey of the theoretical literature on effects of a CBDC on lending rates and loan volumes, see Box 4, below.

Steady State, Versus Adoption, Versus Crisis Times

Central banks need to monitor developments and anticipate changes to the financial system that may occur long after the initial issuance of a CBDC. First, a new steady state for the financial system is likely to emerge only gradually. This adjustment might involve first moving to a higher share of non-deposit funding or higher-remunerated deposits; then passing more costly and/or more volatile funding on to higher steady state loan-rates for bank customers; and ultimately to a somewhat lower provision of bank credit to the real economy in steady state.

Second, along the adjustment path, the system will need to adapt to the operational challenges from the adoption of the CBDC. Even if CBDC adoption is slow at the beginning, as has been the experience in various countries, central banks still need to monitor financial stability because behavioral changes can lead to a more rapid take-up of the CBDC, creating challenges for the financial system.

Third, policymakers need to anticipate that even once the steady state is reached, there can be changes in behavior that occur in crisis times, such as when households switch into the CBDC as part of a flight to safety.

Box 4. Approaches to Modelling the Effect of a CBDC on Bank Lending

Studies that consider the introduction of a CBDC in banking models make different assumptions about bank competition, funding sources and on whether the CBDC can replace cash or a range of deposits.

A standard result from theory is that, when funding costs increase, there will be a pass-through to loan rates, which will reduce credit, as loan demand falls. The strength of the effect depends on the degree of competition in loan markets. Imperfect competition leads to only partial pass-through to loan rates, and a more muted reduction in lending, while the reduction in loan volumes will be more pronounced in markets that are more competitive, so that increases in funding costs are fully passed on.

Box 4. Approaches to Modelling the Effect of a CBDC on Bank Lending (concluded)

However, a range of outcomes can emerge concerning disintermediation because of different modelling choices. Papers differ on whether wholesale funding can be used to replace deposit funding and they make various assumptions on CBDC designs including whether CBDCs are remunerated or not. Some of the modelling choices can lead to an increase in deposits as a result of the introduction of a remunerated CBDC. This typically comes about when households are reducing their holdings in cash or other (time) deposits.

In Keister and Sanches (2023), the banking sector is *perfectly competitive*, banks make zero profits and wholesale funding is not available. Banks are constrained only by the asset pledgeability constraint, and the changes in market rates are reflected in deposits and lending. Introducing an interest-bearing CBDC into a competitive banking sector raises banks' funding costs and reduces credit creation, hence causing some disintermediation. However, the effect of a CBDC can still be welfare enhancing when households value the improved ability to make payments.

Whited et al. (2023) model links between the deposit and lending markets in a model of *imperfect competition* and introduce the CBDC counterfactually as a bundle of existing payment characteristics. Consumers are assumed to have demand for CBDC even when it is not remunerated, since it is modelled as a synthetic bundle of characteristics of other existing payment instruments. The paper estimates the sensitivity of demand to these characteristics and inserts this demand into the model to evaluate the impact of CBDC on bank behavior.

In their model, a non-interest bearing CBDC would capture around 8 percent of the deposit market and lead to just over a one-percentage fall in lending compared to a banking industry without a CBDC. Banks' profits are also reduced, weighing on banks' capital and on their lending capacity. Banks' ability to replace deposits with wholesale funding mitigates the disintermediation effect.[35] However, as wholesale funding is more interest sensitive than deposit funding, banks become more exposed to interest rate risks. In addition, they find an asymmetric impact on banks depending on their size. Because small banks typically have less access to wholesale funding, they have more difficulty to adapt than large banks.

When the CBDC is remunerated, the effects become stronger. Banks would respond by raising their deposit rates, but they would still lose up to 30 percent of their deposits if the CBDC paid the federal funds rate. Similarly, their lending would decline by more than 7 percent compared to a non-CBDC case.

Andolfatto (2020) studies a *monopolistic banking sector*, where the issuance of a remunerated CBDC can improve bank lending. A positive rate on CBDC leads to higher deposit rates that incentivize depositors to save more and lead previously un-banked to switch from cash into deposits. In similar setups, Chiu et al. (2023) and Chang et al. (2023) also find that when the CBDC increases remuneration offered by banks on deposits, this can lead households to want to reduce holdings of cash and to make additional deposits.

[35] See also Chang et al. (2023) who study the CBDC impact on bank disintermediation and find that even if deposits may fall the impact on bank lending is cushioned if banks have access to wholesale funding.

Risks in the Context of Adoption

When the CBDC is first issued, volumes demanded may be low initially, as network effects and inertia in the behavior of households favor the use of existing payment systems. However, it is conceivable that behavioral changes lead to a more rapid-than-expected demand increase for CBDC or a more rapid-than-foreseen fall in bank deposits.

First, CBDC adoption can increase rapidly from a low level, since network externalities in the use of payment systems can give rise to multiple equilibria. When few households use a new payment system, the pay-off from joining the system is very low. When many agents already use the system, the payoff from also joining the system is much larger. This means that both “no one joining” and “everyone joining” are Nash outcomes (see, e.g., Gowrisankaran and Stavins, 2004). The early experience in several countries has been of a slow rate of adoption of CBDC (see e.g., Zamora-Perez et al., 2022), meaning that it has proven difficult for central banks to move beyond an equilibrium where few agents participate in the new payment system. But it cannot be ruled out that there is a tipping point where, perhaps as a result of new incentives, the system flips to an equilibrium where a large number of households and firms decide to use the new service. This may potentially trigger disruptive adjustments, for instance if banks curtail credit to the real economy as part of their response.

Second, if households come to primarily use the CBDC instead of deposit-based payments, the value of continuing their relationship with a bank may diminish. Consequently, they may transfer funds from their checking and savings account funds into brokerage accounts with non-banks (see e.g., Gondat-Larralde and Nier (2006) for evidence on checking accounts being pivotal in households’ relationship with banks). Customers are then more likely to migrate to non-banks if banks are no longer willing to offer credit services to those customers.

Third, a disruption can arise from changes in business-related payments once the CBDC has started circulating. Businesses would typically receive CBDC from their retail customers for purchases made online or at Point-of-Sale (PoS) terminals in stores (see e.g., BIS 2021c), but would likely at least initially pay their suppliers and employees using deposit-based payment systems. Such practices could change once many households and firms are using the CBDC. More firms could then decide to make payroll payments to their work force using CBDC, and could also switch to making payments to suppliers, increasing business-to-business use of CBDC, then potentially leading to much larger volumes of the CBDC being demanded for payments purposes.

Risks in Periods of Stress

Disruptions to the provision of credit can also arise in periods of stress, potentially long after the initial adoption and even once the system has settled into a steady state. As pointed out in the literature (e.g., BIS Innovation Hub, 2021), the existence of a CBDC alongside bank deposits may facilitate run-like behavior in periods of stress. When there are doubts about the solvency of individual banks or about the stability of the banking system – perhaps as a result of an adverse aggregate shock raising loan defaults – bank customers can switch to CBDC.

Digitalization of money makes a run on an *individual bank* easier and faster to evolve. As illustrated by the US regional banking turmoil of Spring 2023, bank runs could nowadays be faster than in the past because of the use of social media and digital banking (see FDIC (2023a, 2023b), FRB (2023), and U.S. Government

Accountability Office (2023), for discussions on bank runs of First Republic Bank, Signature Bank, and Silicon Valley Bank).[36]

Households holding both a deposit account and CBDC can contribute to increasing the speed of such runs. Absent a CBDC, customers would have to stand in line to obtain physical cash at the bank branch, unless they hold a second deposit account with another bank, which enables a digital transfer of deposit-money to that bank. Holding both CBDC and a deposit account enables additional customers to take all funds out of the stricken bank quickly, by switching out of the deposits and into CBDC. In this context, the introduction of CBDC could further increase the probability of a run, and raise substantially the speed at which a stricken bank may be losing deposits (e.g., BIS Innovation Hub, 2021), potentially forcing the stricken bank to liquidate its credit portfolio at fire sale prices.

The existence of a CBDC can also heighten the potential for a run on the *banking system as a whole* (e.g., BIS Innovation Hub, 2021b or Bitter, 2023). Where there are doubts about the solvency of the system, and absent a CBDC, resident households can either obtain physical cash, or wire funds out of the country, in what amounts to capital outflows, provided they maintain a deposit account abroad. With the CBDC, there is a third, and easy alternative, that is for bank customers in the country to switch to the CBDC, thereby exchanging risky claims on the banking system for safer claims on the central bank. System-wide bank runs – such as those observed in the US in the context of the Great Depression (Bernanke, 1983) – would then become more likely at lower perceived risks to the banking system as a whole, and at a higher level of credibility of the local deposit insurance arrangements (BIS Innovation Hub 2021b, Mancini-Griffoli et al., 2018).[37]

System-wide runs into the domestic CBDC may be a concern in particular for reserves currency issuers, or more generally for central banks that enjoy a high level of credibility with their population. A flight to safety could then lead to large inflows into the central-bank issued liability. By contrast, in countries where the credibility of the central bank is weaker, perhaps as a result of a history of inflation, a flight to safety may more likely continue to lead to flows out of the country and into reserves currencies, such as the dollar.

A system-wide run into the CBDC could be met by system-wide "controls" on the conversion of deposits into CBDC, in a manner similar to the use of capital outflow controls in such crisis circumstances currently (IMF 2012). At the level of individual banks, similarly, the bank may refuse demands by customers to purchase CBDC, in a similar manner that a bank may close its doors to customers in the context of a traditional bank run (Diamond and Dybvig, 1983).

Pressures on the system as a whole can also lead to runs on a smaller *set of weak institutions*—those that are hit the hardest by an aggregate shock or that have a high share of deposits that fall outside of deposit insurance coverage limits. In particular, when aggregate shocks – such as increases in interest rates, sharp changes in commodity prices, capital outflows, or a macroeconomic downturn, translate into solvency or liquidity pressures for the banking system, those banks most exposed to the relevant factor will see their

[36] In the case of Silicon Valley Bank run, FDIC (2023b) notes that "The ubiquity of social media and mobile banking may mean that bank runs, when they happen, happen faster" while FRB (2023) points that "Social media enabled depositors to instantly spread concerns about a bank run, and technology enabled immediate withdrawals of funding."

[37] During the Great Depression, deposits fell sharply as people withdrew their money and kept it outside the banking system. Gerali and Passacantando (2007) argue that this reflected a lack of confidence in banks which led to decreased appetite for "inside" bank money and increased demand for alternative payment instruments, in particular "outside" money in the form of currency, gold, and even forms of barter. Accordingly, between 1929 and 1933, the value of cheques handled by the US Fed fell by 57 percent, a contraction in settlement activity more than proportional to the overall contraction in economic activity during the Depression.

solvency take a relatively bigger hit. Where those same banks maintain uninsured deposits or are not protected by a fully credible deposit insurance scheme, deposit outflows towards CBDC would likely be most pronounced. Thus, in the case of negative aggregate shocks, runs on the weakest institutions are likely to emerge first, and may or may not then trigger system-wide bank runs eventually, depending on whether the initial runs can be contained.

As we will discuss further below, these weaker banks may well have to borrow heavily from the central banks to meet outflow pressures, using lenders of last resort facilities, unless the design of the CBDC reduces the potential for the runs to occur. CBDC issuance could also mean that the liquidity problems that have been prominent in the NBFI sector could become more pronounced during times of stress, unless central banks decide to revisit their lists of eligible counterparties (see further IMF 2023a).

5. Policy Options to Mitigate Adverse Effects of CBDCs on Financial Stability

The section discusses a central bank's policy options to mitigate any detrimental effects of CBDC on financial stability. This includes macroprudential policy, monetary policy and central bank market operations, options for the design of CBDC, and other private digital methods of payments using the central bank settlement system.

We find that mitigating the emerging risks by macroprudential or financial sector regulatory policies alone is likely to be difficult. Moreover, monetary policy and changes to central bank market operations may not be able to fully neutralize the effects from CBDC, while an expansion of central bank lending can put central bank balance sheets at risk.

Thus, the primary contribution towards mitigating policies would need to come from the appropriate design of the CBDC itself. In this regard, designs that encourage the use of the CBDC as a means of payment, rather than as a store of value, are likely to be useful to increase the benefits of a CBDC while avoiding costs for financial stability. This can be achieved by striving for solutions that make CBDC widely available (extensive margin), while inducing households and firms to hold small amounts for making retail payments (intensive margin). The policy maker can achieve such outcomes by, for example, introducing holding caps, setting zero or negative remuneration, and ensuring interoperability with the banking system. Finally, using the CBDC to promote payment systems based on bank deposits could ensure the efficiency of the payment infrastructure while containing detrimental effects on financial stability.

Macroprudential Policy

In several scenarios, prudential ratios are affected by the introduction of a CBDC, as illustrated in Section 3. In these scenarios, both the LCR and the NSFR are expected to fall with the drop in deposits, implying that some banks may hit the prudential floors of these ratios. In some scenarios (Scenario 2-B), where banks rely on wholesale funding to purchase government bonds (then used as collateral), there can also be an increase in leverage, and a corresponding decrease in the LR that can make it fall below its regulatory minimum.

Policy makers could be tempted to relax the prudential requirements affected by the introduction of the CBDC to avoid a forced deleveraging that would be detrimental to economic activity. Supervisory authorities would however likely oppose such a relaxation on the ground that this would jeopardize financial stability. Moreover, given that the introduction of the CBDC and the associated drop in deposits is likely to increase funding risk for banks, all else equal, it would be difficult to justify a relaxation of prudential requirements. There is little reason, therefore, from a financial stability perspective, for the macroprudential policy stance to be loosened in these scenarios.

Heightened macro-financial vulnerabilities could instead warrant an expansion of the macro-financial toolkit in some countries or a tightening of existing tools on the banking system. For example:

- Banks' capital buffers could be hiked ahead of the launch of the CBDC to reduce incentives for greater banks' risk taking from a drop in profitability. Higher capital buffers could help reduce risks from a strengthening of the bank-sovereign nexus in the context of the issuance of CBDC. And they could finally contribute to a (perceived and real) strengthening of the banking system and reduce the likelihood of runs away from bank deposits and into the CBDC.
- Caps on FX funding or LCR ratios that apply separately for each major funding currency could be introduced in jurisdictions where banks respond to the loss in deposits by increasing reliance on FX funding, and where tools to control the resulting risks are not yet available.
- Countries could also introduce stressed debt service-to-income ratios to address the higher financial instability caused by more volatile lending rates.

Finally, if the introduction of CBDC is assessed to lead to an increase in banks' funding from domestic or foreign NBFIs (Section 4.4), this would underscore the need to achieve progress in the macroprudential regulation of the NBFI sector. Increasing the resilience of market-based financing could include strengthened regulation of money market funds and open-ended investment funds if the importance of these entities as providers of funding for the banking system rises.

As discussed earlier, market-based finance has been prone to disruptions during the GFC and the COVID-19 pandemic (see, e.g., Gorton 2012). An increased reliance on such funding would necessitate further efforts to deliver the regulatory policies that aim to make such funding more resilient, as is being discussed at the international level.[38] As the NBFI sector is diverse and there are differences in composition and business models across jurisdictions, achieving one-size-fits-all policies is unlikely to be feasible or desirable. On the other hand, an uneven application of policies opens up the scope for regulatory arbitrage. In the face of the resulting difficulties in making progress on the macroprudential regulation of the fund sector, central banks may want to seek other policy measures to limit the increase in the reliance on market-based funding in the wake of the issuance of the CBDC.

More generally, although macroprudential measures could be used to limit some of the potential adverse financial stability outcomes, in the scenarios where deposits decline materially, in steady state, in the transition, or in crisis times, it is unlikely that policy makers can rely on macroprudential policies alone. First, macroprudential policy tools are known to work imperfectly. Second, macroprudential policies cannot counter the possible drop in the supply of credit to the economy that may be due to higher funding costs or more

[38] This includes the ongoing work to improve open-ended investment fund resilience against liquidity risks (IMF, 2022b, FSB, 2022).

frequent depositor runs on the banking system. This suggests that adjustments to other central bank policies (sub-section 6.2) should also be considered, while appropriate CBDC design options (sub-section 6.3) may ultimately hold most promise in defending against financial stability risks.

Monetary Policy and Central Bank Market Operations

Monetary Policy

In principle, the central bank can take changes in financial conditions into account when setting its policy rate to achieve its ultimate price and output stability objectives.[39] It is therefore worth considering whether the central bank could adjust its monetary policy to offset the impact from CBDC issuance on interest rates in the context of adoption or in steady state. For instance, the central bank could tighten (loosen) monetary policy if financial conditions are loosened (tightened) as a result of the introduction of the CBDC. It may thereby at least in part undo a parallel shift in the yield curve that could arise from the issuance of CBDC.

However, the impact on interest rates may not be uniform across markets, making it difficult to determine the appropriate policy response.[40] For example, as already discussed, deposit rates may move upward with the issuance of CBDC due to an increase in competition. And when banks pass on the increase in their funding costs this will also increase the lending rates charged to households and firms. On the other hand, the issuance of a CBDC might reduce yields on government bonds when additional reserves need to be generated by asset purchases or collateralized lending by the central bank to the commercial banking system (see Table 2).

In any event, in a situation where interest rates do not all move in tandem, but issuance of the CBDC induces a shift in relative prices, the central bank cannot easily neutralize the effects by a change in the policy rate. Similarly, where doubts about the strength of the banking system induce changes in the relative share of households' holdings of deposits versus CBDC in a crisis, a change in the policy rate is not the right tool to address these doubts, and other policy levers need to be considered.

Central Bank Market Operations

It is useful to consider whether there may be scope for the central bank to change the terms of its lending to the banking system to mitigate the impact of CBDC issuance on commercial banks' lending. This would explore further the reasoning in Brunnermeier and Niepelt (2019), that when households expand CBDC holdings at the expense of deposits, this need not undermine financial stability, because the central bank can always lend the proceeds of the CBDC issuance back to the banking sector, thereby enabling banks to continue lending to the real economy just as before. Issuance of CBDC would then give rise to a substitution of one type of bank funding (deposits) by another one (central bank lending) without necessarily affecting the volume of loans available to the real economy.

Indeed, as we highlight in our scenario analysis above, unless (1) reserves are ample and can then be drawn down to purchase the CBDC, or (2) additional reserves are created through asset purchases, an expansion of central bank lending to the commercial banking system through its open market operations is the

[39] See the IMF blog "Central Banks Can Fend Off Financial Turmoil and Still Fight Inflation" by Adrian, Gopinath, and Gourinchas for more detailed discussion about the trade-off between price and financial stability during times of stress.

[40] The issuance of CBDC can affect potential output by reducing credit provisioning due to the increase in lending rates. The primary role of monetary policy is to smooth out the business cycle by stabilizing the demand side rather than by affecting the supply side and potential growth rate.

only other way in which the central bank can generate the additional reserves needed for the banking system to purchase the digital currency from the central bank (see above, Table 2).

In practice, however, even when the central bank decides to expand its lending to the commercial banking system in open market operations, there are at least three reasons why such lending may not neutralize the detrimental effects of CBDC issuance on commercial bank lending.

First, central bank funding will typically be more expensive than deposit funding. The rate commercial banks pay on (insured) checking accounts is typically at or close to zero. However, the interest rate the central bank charges on lending in open market operations is tied to its policy rate, and therefore typically positive. Thus, banks experience a higher funding cost, resulting in a negative effect on profits, and potentially also on lending volumes, even when they can tap additional central bank lending (as we have illustrated in Table 3, for Scenarios 2 and 4).

Second, central banks typically lend only against high-quality and liquid assets in their regular open market operations. As we have shown above, an important implication for banks of the drain in deposits is that this puts pressure on banks' LCR metric. However, when central banks make loans only against high-quality assets, the amount of unencumbered HQLA that banks have available to meet the LCR requirement will go down, so that pressure on the LCR will persist even if central banks make additional loans to banks in standard open market operations. Some authors have argued that central banks may be willing to expand the collateral they accept beyond HQLA when this is necessary to ensure sufficient funding for the banking system to purchase the CBDC (e.g., Burlon et al., 2022). And when central bank lending can be collateralized by pools of bank loans, this can contribute to help banks maintain their provision of credit to households and firms.[41]

However, many central banks may not be able or willing to broaden the collateral they accept when they start issuing CBDC (see Burlon et al. (2022) for example) because of the associated increase in central-bank balance sheet risk. In Emerging Market and Developing Economies (EMDEs) in particular, there may be less transparency about loan quality and inadequate infrastructure to evaluate the quality of broader collateral. Moreover, loosening collateral requirements means that the credit risk inherent in lending to the real economy is transferred to the central bank, as it accepts either low-quality or less liquid assets as collateral. These considerations will typically make it unattractive for central banks to expand their lists of collateral in steady state market operations.

Third, when central banks lend to the commercial banking system in standard open market operations, they do so typically at only very short maturities, such as a day or a week, so that a large share of the lending to the commercial banking system is typically rolled over at such short intervals. If central bank funding is made available at such short maturities, the additional lending received by banks will not alleviate pressure on banks' NSFR. This is because short-term funding by the central bank will not count as long-term and stable funding even if that funding is typically rolled over by the central bank.

Of course, central banks could consider making advances to the commercial banking system at longer tenors to provide the funding necessary for the banking system to purchase the CBDC. If the central bank is willing to increase the maturity of its lending beyond one year, the banks could tap into this lending and improve their NSFR, which otherwise stands to deteriorate in some of the scenarios. And indeed, some advanced economy central banks, such as the ECB, are known to have offered long-term refinancing operations (LTROs)

[41] However, central bank's collateralized lending or purchases of HQLA assets would not have an effect on the banks' LCR ratios.

in response to liquidity pressures that emerged in the context of the GFC and the more recent COVID-19 shock.

However, for many central banks it may not be a viable option to extend term lending programs beyond crisis times and for such lending to be made available to the commercial banking system in steady state. Were central banks to be doing this, they would essentially replace the banking system as the main provider of maturity transformation, as the central banks are then taking short-term CBDC inflows and lending the proceeds long term to the commercial banking system. In practice, although some central banks have introduced longer tenors for their lending, this was done to support the economy in an environment of aggregate liquidity stress.[42] Thus, they may want to scale down such long-term lending in normal times to avoid providing such loans in steady state.

Lender of Last Resort

Changes to central bank operations could be considered more seriously to prepare central banks to mitigate the detrimental effects to the financial sector in crisis times.[43] As discussed, a key concern is that upon observing or hearing about stress in the banking sector, households might move significant amounts of deposits into CBDC. In such an episode of a "digital bank run", the central bank can provide an emergency lending program (lender of last resort) for the banking sector to prevent a collapse due to a lack of liquidity at one or more afflicted banks.

Central banks' ability to act as the lender of last resort has provided an essential backstop in supplying emergency funding to the banking sector in past financial turmoil and it can mitigate the economic disruptions that arise from financial panics. The central bank's role as a provider of lender of last resort could therefore also be effective in the case of a "digital bank run". Indeed, as observed by Brunnermeier and Niepelt (2019), when funds flow out of deposits and towards the central bank, the central bank can simply lend these funds back to the commercial banking system.

However, there can also be practical challenges that would need to be considered carefully, and which could require changes to existing practices for many central banks.[44] First, while the central bank may stand ready in principle to support the emergency liquidity needs of the system, traditionally, it would only lend to solvent banks, and against collateral, such as government bonds, to avoid any eventual losses on its own balance sheet. However, as set out in Section 5.7, the weakest banks may be the ones more likely to experience the most abrupt deposit outflows in case of negative shocks. If the more fragile banks are those where solvency is most likely to be in doubt, this reduces the scope for traditional lender of last resort (LOLR) operations. More generally, banks' assets are by design often illiquid or not readily marketable, blurring the distinction between illiquidity and insolvency in periods of stress.

If the design of the CBDC leads to a greater frequency or virulence of depositor runs, LOLR operations would need to be made more effective. While central banks may need to continue to ensure that LOLR is provided only to institutions that the central bank deems to be solvent, such a solvency assessment can in

[42] While the ECB offers targeted longer-term refinancing operations (TLTROs), which provides long-term funding at attractive conditions, this is targeted lending framework, and it is introduced to strengthen the accommodative monetary policy stance in adverse macroeconomic conditions.

[43] See G30 Working Group on the 2023 Banking Crisis (2024) for a discussion of how the LOLR regime can play a role in limiting contagion when bank failures occur, based on the studies of bank failures in March 2023 in the United States and Europe.

[44] See, for example, Choi et al. (2021) on the quality of collateral and the effects of liquidity creation by the lender of last resort.

practice be forward-looking and assess whether the bank requesting support has a credible prospect to regain solvency conditional on liquidity support having been provided.[45]

Proposals could also be considered for changes in protocol ex ante that expand the collateral deemed sufficient for such purposes. This could involve more systemically evaluating and assigning haircuts to a range of assets on commercial bank balance sheets, including loans and other illiquid assets. When commercial banks preposition such assets with the central bank, this can ensure that advances can be made against them as needed, avoiding the operational challenges of having to pledge and value such assets at short notice in the midst of a crisis. When such an effort is instead made ex ante, this could turn a large part of the commercial banks' illiquid assets into collateral that can be accepted by the central bank provided the central bank commits to lend only a proportion of the value of the assets (see Chapter 5 of King (2016) for an in-depth discussion). Thus, the central bank would become more effective in providing liquidity to fragile banks as lender of last resort.

The ability of the central bank to provide LOLR in the context of digital runs on the CBDC can also be eased when the central bank as operator of the payment system on which the CBDC is exchanged, is able to monitor which banks are affected by runs into CBDC (Keister and Monnet, 2022). This could facilitate a more timely liquidity injection, and help the central bank to more elastically accommodate runs out of deposits and into CBDC in a manner that helps banks survive such runs without having to fire sell illiquid assets or to close.

Overall, the changes that the central bank can make to its operational framework can mitigate some, but not all of the financial stability impacts that we find arising in some of the scenarios. Moreover, the mitigation of financial stability risk occurs at a cost of increased risks to the central bank's balance sheet, as lending to the commercial banking system – and ultimately the real economy – expands. This would reduce the attractiveness of these policy options outside of periods of stress, when an aggressive reprovision of liquidity to the banking system may be needed to reduce the impacts of runs into the CBDC. And while the steps discussed in this section can reduce the impact of runs on individual banks, by preventing closure or fire sales, reducing their likelihood would require other policy options, including an examination of design options for the CBDC, as we discuss next.

Central Bank Design of CBDC

This section examines how the design of the CBDC can alleviate some of the financial stability concerns associated with a CBDC. We consider three interrelated design elements of a CBDC —including holding caps, zero or negative remuneration, and interoperability with the banking system.

Designing CBDC to Reduce Competition with Deposits

Central banks that are considering CBDC primarily as a retail payment instrument are likely to consider designs that facilitates this function, that is, foster a use for small payments by firms and individuals. On the other hand, the likelihood of the adverse effect on financial stability described here depend on the degree to which CBDC

[45] In principle, the solvency assessment for LOLR purposes could be forward-looking. For instance, the central bank could assess whether the bank requesting LOLR support has a credible prospect to maintain or restore appropriate capital adequacy in the near-term (within 6 months), thereby allowing the provision of LOLR support to temporarily undercapitalized banks (e.g., if they have a recapitalization prospect). Furthermore, the provision of LOLR support to a bank with uncertain solvency can be possible under a government guarantee.

would crowd out bank deposits. Central banks that want to achieve the policy objectives of CBDC therefore want to consider how this can be done without causing unnecessary disruptions.

Money fulfils three classic functions: means of exchange, unit of account, and store of value.[46] While CBDC must fulfil all three at a basic level, the goal for a central bank is to ensure that the function as a means of exchange is more prevalent than the function of store of value. CBDC should, in other words, be primarily used when people pay and not when they save.

The issuing central bank therefore faces a trade-off when it comes to target adoption and usage of CBDC. It wants CBDC to be adopted sufficiently to promote the chosen policy objectives (as set out above) but not to the extent that it crowds out bank deposits on a scale that would trigger the more adverse scenarios covered in this paper. On the other hand, if it strives to reduce the attractiveness of CBDC to avoid crowding out bank deposits, adoption may be too low to promote the policy objectives of the CBDC.

Not all policy objectives would necessarily need a large degree of CBDC adoption to be achieved. For instance, the policy objective of ensuring confidence in the monetary system through ensuring convertibility of private money into public money would not necessarily depend on a large daily usage. Neither would the policy objective of resilience through providing a backup system if other main digital payment systems are disrupted. Central banks have therefore so far been careful in designing CBDCs to retain the competitiveness of bank deposits, in line with the objective of "doing no harm."

Network effects in favor of already existing forms of payments, as well as established habits of the population, might mean that CBDC adoption can be expected to be slow in some jurisdictions. However, once a critical mass of users has been reached and network effects for CBDC are achieved, a rapid adoption cannot be ruled out. Central banks need to keep this possibility in mind and explore ways to mitigate risk of disruption in the process of adoption. It is also important to think ahead on how the design of CBDC can shape the behavior of the systems in times of stress.

We are discussing three main ways. The first is quantitatively restricting the amount of CBDC that is issued or is available to individual households. The second is to design the remuneration of CBDC in a way that it is less attractive compared to deposits. Ways of increasing interoperability with existing bank deposits or tokenized deposits are also coming into focus.

Caps on Holdings of CBDC

Quantitative restrictions can be designed in different ways. First, a cap on total issuance of CBDC could be considered. This would cap the overall adoption of CBDC to a desirable level. An important advantage of this approach is that the central bank can very easily implement it by simply stopping further issuance of the CBDC when the desired amount is reached, much like a central bank is able to control to total amount of reserves within the banking system.

However, such an aggregate cap would render a CBDC different from cash in circulation, since central banks always stand ready to provide as much of that cash as is demanded in the economy. This would be unattractive for a central bank that would like for the CBDC to be just a digital version of cash in circulation and for it to always trade against cash at par. Moreover, a potential disadvantage of an overall cap is that some individuals could hoard the CBDC early in the issuance, while others would have increasing difficulties

[46] These features were first described by Stanley Jevons in 1875.

acquiring them as the cap is reached.[47] Another potential disadvantage is that in extreme situations such as financial crises, in which holders of money deem CBDC to be a safer asset than bank deposits, a secondary market with a higher price of CBDC than par value may emerge.. In the same vein, Carapella et al. (2024) argue that aggregate limits create an incentive for a pre-emptive switch to CBDC, as depositors might fear that the aggregate limit is reached, especially in times of stress.

Authorities also have the option to limit the amount of CBDC one person can hold. CBDC is usually held in a digital wallet (most often an app running on a device) or hardware wallet (for instance a physical card, or a smartwatch). Both types of wallets can be designed with caps so that the amount of CBDC held in them cannot exceed a certain level. In addition, it is possible to connect a CBDC wallet with a deposit account so that if too much CBDC is sent to the wallet the excess is automatically converted to a bank deposit account (see Bindseil, 2020). This function has already been introduced in the Bahamas Sand Dollar CBDC, for example, and we discuss it further below.

A key disadvantage of a cap is that it may be prone to circumvention, such as by households holding several wallets with different providers. To avoid circumvention of limits, mandatory identification could be introduced, so that one person cannot hold more CBDC than is permitted under the cap even when holding several wallets. Digital wallets could for instance be bundled with a mandatory digital identity certification, such as envisioned in the European eID initiative.[48]

Such measures may be less attractive where the CBDC is meant to offer a near anonymous means of payment, as does physical cash. However, there are also variations on how to use caps to disincentivize holding of CBDC. For instance, as discussed below, a negative interest rate may be applied in case the CBDC amount exceeds a certain cap. In general, different wallets also have different levels of anonymity and demand for Know Your Customer/Anti-Money Laundering (KYC/AML) controls, so that wallets with a low cap are more anonymous and wallets with a higher cap demand more extensive identification.

Caps can also apply to the size and frequency of transactions. These are applied, for instance, on offline payments in the Chinese e-CNY.[49] Such caps are by their nature easier to enforce, since they can be built into the design of the payment system itself on which the CBDC is circulating. In principle, a cap on the size of transactions should make it more burdensome to use the CBDC for larger transactions, such as payroll, or real estate purchases. It is likely, however, that such caps could be circumvented by algorithms that split the transactions in a manner that conforms to the limit and still work essentially instantaneously. Nevertheless, a combination of a cap on the amount and on the frequency of transactions could be designed to be effective in limiting the use of the CBDC to retail contexts.

In case of a digital bank run, central banks could also stop convertibility into CBDC. This would amount to a sharp cap applied temporarily on the aggregate amount of CBDC in circulation, to break a run on the banking system. Central banks could design a “kill switch” into the CBDC system that would allow instant stopping of conversion and ensure that users are informed that mass flight from deposits into CBDC will activate the switch. Such a cap would however not be practical when the run is on an individual firm, since conversion of even all of this individual firms’ deposits to CBDC may not materially affect the aggregate amount of CBDC in

[47] That said, negative rates on large holdings (as discussed just above) could ensure that the CBDC flows where it is needed for payment purposes.

[48] European Commission (2023).

[49] Soderberg et al. (2022).

circulation. In such a situation it would rather be the individual bank that would have to disallow such transactions, then essentially closing itself down.

While caps on holdings are technologically possible and a potentially promising tool, practical applications need to consider the scope for the circumvention of such caps, especially when the cap is otherwise calibrated to reduce the scope for larger payments. For instance, if the verification of the user identity is deemed necessary to ensure that users do not circumvent caps by holding multiple wallets, it would imply a tradeoff with the potential policy objective of privacy and anonymity, which could in turn undermine support for the CBDC. Central banks will need to consider whether this price is worth paying. Indeed, in practice, the incentive for households to hold several CBDC accounts to circumvent the cap may not be very strong as long as the CBDC remains remunerated at zero, rather than at a positive rate. More generally, central banks will need to consider carefully how to calibrate the cap to ensure that the CBDC meets its desired "use case", while reducing sufficiently the adverse effects that it is assumed to address.

Remuneration of CBDC

Currently, all CBDCs in circulation or planned have a zero-interest rate. The motivations for the absence of remuneration include technical or legal difficulties to apply interest rates in some CBDC systems, and also a wish to mimic cash.[50] After all, the idea of a CBDC is to be a digital version of cash, which also does not pay interest. Moreover, remunerating the CBDC issued to households and firms would reduce central bank profits, potentially substantially, depending on the volumes held by the population. But most central banks also explicitly state that zero interest rate is a design choice aimed at reducing the attractiveness of CBDC as a store of value versus bank deposits.

There are two reasons why central bank may still consider positive rates of remuneration. The first is that central banks could increase the attractiveness and rate of adoption of CBDC through a positive interest rate. This would make it easier to achieve the desired policy objectives but would also increase competition with bank deposits and worsen the risks of credit disintermediation. Indeed, when the CBDC works well as a means of payments for households and firms, and also carries a positive interest rate, holding the CBDC may strictly dominate holding checking deposits for almost all households, leading to large shifts into the CBDC, unless banks remunerate current account holdings at least at the same rate, thereby eroding banks' franchise value. The second reason in favor of a positive and variable interest rate is that it could potentially enhance the pass-through of monetary policy, though at the cost of exacerbating the financial stability risks we have drawn out.[51] Positive interest rates could more safely be considered where the exchange is with physical cash, rather than reserves (Scenario 0), however, a positive rate could then still lead to deposits being drawn down in equilibrium.

While a zero remuneration is therefore an important mitigant of financial stability risks, other renumeration options could potentially help further alleviate the abovementioned policy tradeoff. A tiered wallet structure could, for instance, allow for different kinds of interest rates on different sizes of holdings. Negative interest rates could be applied on holdings over a particular threshold, which would make it possible but costly to hold a large amount of CBDC (Bindseil et al., 2020). In such a scheme, moreover, the interest rate on CBDC could be at most zero to limit competition with deposits.

[50] See for instance Sveriges Riksbank (2022).

[51] For more on this see Das at al., forthcoming.

While negative interest rates beyond a certain amount might be attractive in theory, as being more market-friendly than a cap, negative rates on money balances may be unpopular with households, who will see their money be subject to a new tax, in a world where cash had always had a zero-interest rate. This could be politically unpopular and could undermine support for the CBDC. A quantity constraint on CBDC holdings, by contrast, is an element that households may more readily accept, especially if incoming surplus CBDC is deposited in the household's deposit account at no cost—as we describe just below.

Interoperability with the Banking System

Interoperability between CBDC and bank deposits can help mitigate adverse effects on financial stability. An important element is convertibility between CBDC and bank deposits in the same way that bank deposits today are convertible to cash.[52]

In the absence of the CBDC, cash is the only form of central bank money available for retail use. However, private banks typically provide the service of converting commercial bank money held in deposit accounts into physical central bank money through, for instance, ATM machines. Similarly, banks can perform an important function in the distribution of CBDC. And ensuring that offering CBDC to end users will be a sustainable business model for banks could soften the policy tradeoffs described in the sections above.

In particular, in case a bank loses deposits changed into CBDC, but this is kept within a wallet offered by the bank itself, the bank can retain its customer. It can then continue to offer other services in addition to providing access to and payments with CBDC. On the other hand, if deposits are exchanged for CBDC held in wallets offered by NBFIs, the ability of the commercial banking system to continue to offer payment and lending services to the public is reduced.[53]

CBDC could also be seamlessly embedded in the commercial bank service structure. For instance, CBDC wallets could be fully interoperable with bank accounts so that funds can flow between them instantly when a payment is made using the CBDC. Alternatively, a prepaid volume could be stored in the wallet but surpassing this volume through a payment could automatically transfer funds from the bank account.

In the limit, interoperability could be designed such that CBDC is created only in the instant that it is needed for a payment and is retired and converted to commercial bank money in the instant it is received. Such a design could reduce substantially the overall amount of CBDC that is in issue at any given moment in time. Such interoperability would also allow users without a CBDC wallet but with a bank account to still be a valid recipient of a payment in CBDC.[54]

Overall, the use of design features of the CBDC could foster the use of the CBDC as a means of payment rather than as a store of value. Such designs may mitigate substantially any possible adverse effects on credit

[52] For a discussion on the role of commercial banks, see for instance Seidemann (2021).

[53] Even if non-banks are included as intermediaries in the distribution of CBDC, banks will retain a role, since they are typically the only intermediaries able to directly interact with the central bank, such as through Real Time Gross Settlement accounts. Non-banks involved in the distribution of the CBDC will first acquire CBDC through debiting their client deposit accounts with the banks, which then flows through to a purchase on behalf of the NBFI that involves an exchange of CBDC for some of the central bank reserves held by the commercial bank. Such an arrangement is currently being used, for instance, in the Bahamas Sand Dollar CBDC.

[54] Central banks are also considering designs that enable interoperability between the CBDC and deposit-based digital monies. For example, the central bank of Brazil's 'Real Digital Initiative' seeks a coexistence of digital real with private digital currencies. These private digital currencies would be issued by regulated institutions on a smart-payments platform that is controlled by the central bank overseeing the platform, as further discussed in the BCB's financial stability report and the guidelines for the digital real (BCB 2022, 2023).

intermediation and financial stability. The key idea here is to make the CBDC widely available (extensive margin) to increase the benefits coming from network effects, while discouraging households from holding large amounts (intensive margin) for savings purposes. The central banks' choice of remuneration, holding caps and interoperability with the banking system can all contribute to this, and reduce the potential for adverse financial stability effects.[55] The exception here is the loss of information on household payment activity that arises regardless, unless the system is designed to provide this information to the banks.[56]

Wholesale CBDC and Efficiency of Retail Payments

If concerned about the possibility to contain financial stability risks from retail CBDC, central banks can also consider exploring a wholesale CBDC—i.e., for use by financial institutions only—to achieve some of their policy goals, including increasing the efficiency of retail payments. For instance, a wholesale CBDC could be important to stimulate interoperability between different bank initiatives to tokenize deposits that are available to the retail customers.[57] A wholesale CBDC could be useful in providing for the settlement of interbank claims that arise from the exchange of tokenized deposits in such systems. The settlement would take place in central bank money to help ensure the singleness of money.

For instance, in the U.S., a consortium of banks have launched a tokenized deposit called USDF.[58] This latter introduces a more efficient digital exchange of existing bank deposits.[59] In the case of USDF, the exchange of these tokens takes place on a blockchain built by the issuing banks. The clients' transactions create net positions between the banks in the consortium that need to be settled with interbank transfers of central bank money, such as on Fedwire (in the absence of a wholesale CBDC).[60]

When coupled with a wholesale CBDC in an integrated platform, similarly, tokenized deposits can retain ultimate settlement of interbank claims in central bank money, ensuring use of the central bank liability as a means of payment rather than a vehicle for household savings. Such deposits could be operated within the existing bank regulatory framework where participating institutions and hence their deposits are covered by deposit insurance, anti-money laundering and consumer protection regulations (see BIS 2023a).[61]

CBDC designs that enable further development of private deposit-based payment solutions – such as tokenized deposits or fast payments – have no direct effect on credit intermediation. Such advances could therefore be another option to improve the payment infrastructure and preserve the singleness of money while containing potential negative effects of a retail CBDC on financial stability.

[55] Several major central banks state their point of views on the levels of the holding caps they are considering to impose. The Bank of England proposes a limit of between £10,000 and £20,000 per individual to ensure most of the people could receive their pay in digital pounds according to Cunliffe (2023). On the other hand, the ECB considers more restrictive limit, which is around 3,000 to 4,000 digital euros per capita, according to Panetta (2022).

[56] If households mainly use CBDC as a means of payments, banks' ability to assess borrowers' quality may be significantly lowered, as described in section 4.2. This issue would be avoided if each bank access to the transaction data as an intermediary so that they can establish a credit history of each depositor. However, they might not be able to access this transaction information because of legal constraints in privacy. Moreover, some central banks consider the possibility of implementing the design of CBDC which ensures some anonymity (see e.g., European Central Bank 2019), implying that detailed payments information will be unavailable in this design framework.

[57] See for instance the guidelines of the digital real, Banco Central do Brasil (2023).

[58] JPMorgan has also launched a tokenized deposit.

[59] It is useful to distinguish between assets that are exchanged and mediums of transferring the assets as described by the NY Fed blog. Bitcoin Is Not a New Type of Money - Liberty Street Economics (newyorkfed.org)

[60] See also https://usdfconsortium.com/about-us/ under "Illustrative Deposit Tokenization under USDF".

[61] The Future of Payments Is Not Stablecoins - Liberty Street Economics (newyorkfed.org)

Other Financial Sector Regulatory and Banking Sector Policies

Outside the realm of payment system design, a range of additional policies not discussed in the previous sub-sections could, to some extent, mitigate potential adverse effects on financial stability. As argued above, the design of the CBDC can be very important. However, depending on the success of the design in reaching all its goals, further policy-relevant issues may nevertheless emerge. In particular:

- In countries where the banking sector is fragile, the introduction of CBDC could be particularly risky, because the drop in deposits or the rise in the cost of funding would further increase banks' vulnerabilities. Authorities in these countries should therefore make sure they strengthen the banking sector before launching a CBDC, by addressing any structural factors behind the weakness of banks, requiring higher capital levels for banks, and ensuring deposit-taking institutions are well supervised and regulated.
- In countries with gaps in the supervision and regulation of banks that are "too important to fail", and policies identified by the FSB related to their resolution, including data availability, are not yet in place, such gaps should be addressed as a matter of priority, prior to a widespread CBDC launch, when the latter is expected to lead to exits and bank consolidation.
- More broadly, comprehensive supervision and regulation of the banking sector as a whole is important to protect against weaknesses in the banking system, reducing the chance that vulnerabilities are exposed by a greater likelihood of large shifts or from bank deposits and to the CBDC.
- A strong and credible deposit insurance framework would be desirable – in cases where the appropriate preconditions for deposit insurance are met – to reduce the likelihood of significant deposit outflows in favor of CBDC in crisis periods. Without strong deposit guarantees, households might choose to replace a large volume of deposits with CBDC to conserve their wealth when they fear for a bank's solvency. A sufficiently large coverage limit, as well as fast and reliable processes for depositors to receive compensation is needed to reduce such incentives to run on stricken banks.
- More broadly, independently of whether CBDC or private digital monies are being issued, considerations should be given to increase the resilience of the system to cyber-attacks and fraud that may become more likely as digitalization of the payment landscape continues (see BIS (2023b) for more detailed discussion). This could include efforts to maintain the use of physical cash in the economy alongside digital monies, so that a robust alternative payment system stays available if digital monies are subject to outages.

6. Conclusion

The financial stability implications of the issuance of a retail CBDC can be mild, or material, depending on the design of the CBDC, the resulting volume of CBDC, the central bank's strategy for issuing it, as well as pre-existing conditions that help shape the competitive reactions of the banking sector.

As we highlighted in a range of scenarios, the adverse effects on the banking system become larger when the replacement of deposits is greater. However, in scenarios where the issuance of the CBDC leaves the size of the central bank balance sheet unchanged—as the issuance of CBDC is met one for one by a drawdown of physical cash held by households or excess reserves held by the commercial banking system, adverse effects

on financial stability are unlikely to be material. This conclusion holds even if the CBDC replaces deposits. Some effects can still arise depending on the design of the CBDC when a loss in deposits leads to a loss in borrower information.

By contrast, in scenarios where the issuance of the CBDC requires the central bank to generate a prior increase in reserves to enable commercial banks to buy the CBDC, issuance of the CBDC leads to an expansion of the central bank's balance sheet. In these scenarios, adverse effects on financial stability are more likely to occur, through an increase in funding costs or a more volatile funding structure for banks, as the commercial banking system needs to ramp up borrowing from either NBFIs, the central bank, or both. In some of these scenarios, the sovereign-bank nexus may be strengthened, as more high-quality collateral is needed to accommodate greater borrowing from the central bank.

In these scenarios, competitive reactions of the commercial banking system can exacerbate the effects on financial stability. First, when commercial banks raise deposit remuneration to reduce the outflow of deposits, funding costs on the remaining deposit base increase. Second, pressure on bank profitability can lead banks to take greater risks, or exit, especially when bank capitalization is thin. Finally, by increasing the cost and volatility of the funding of banks, the expansion of the central bank balance sheet may lead to some crowding out of the provision of credit to the real economy, as banks pass on higher funding costs and charge higher rates on loans to households and firms. However, such effects are likely only when the CBDC leads to an expansion of the CB balance sheet. In scenarios where the CBDC instead leads mostly to a reduction in cash or reserves, there is no such pressure on bank funding costs or loan rates.

Adverse effects on financial stability can arise from changes in the structure of the financial system in steady state when the CBDC issuance replaces deposits and is large enough to require the prior creation of additional reserves. They can also materialize due to rapid changes from multiple adoption equilibria, as well as in crisis times, when doubts about the solvency of individual banks or the system can lead to runs away from deposits and into the CBDC.

Mitigating the emerging risks through macroprudential or financial sector regulatory policies alone is likely to be insufficient. Macroprudential policy can increase banks' resilience but cannot address the risk of liquidity pressure or disruption of banks' credit intermediation by CBDC. In addition, financial stability concerns come to the forefront when the CBDC yields a larger role of market-based finance and NBFIs in banks' funding. Given the diversity of NBFIs across actors and jurisdictions, and their international nature, achieving substantive progress in their macroprudential control remains a challenging endeavor.

Central bank lending operations can help reduce detrimental financial stability impacts on the banking sector, in principle both in steady state and in crisis times, when the central bank is willing to provide emergency liquidity to banks that are subject to runs into the CBDC. However, an expansion of lending operations against a broader set of collateral and at longer loan tenors would require that the central banks be comfortable with possible losses and managing problem loans. While making such changes to lending operations in steady state is therefore not typically palatable to central banks, a greater use of ex ante positioning of illiquid assets and the assigning of haircuts on these assets for emergency operations are useful to consider.

CBCD design features hold most promise for alleviating financial stability concerns when they can be tailored to foster the use of the CBDC as means of payment, while discouraging large holdings that would hamper credit intermediation or lead to a substantial shift towards wholesale funding of the banking system. When remuneration of the CBDC is low—at zero or potentially negative for larger volumes held, limits to

holding CBDCs and possible interoperability with the banking system would guarantee that the CBDC can be used for transactions, while discouraging its use as a store of value, thereby reducing any adverse financial stability effects as CBDC adoption advances. Similarly, when the CBDC is designed for “wholesale” use among the operators of deposit-based payment systems—including those based on tokenized deposits, adverse impacts on the financial system can be largely avoided. A well-designed CBDC could then co-exist with private payment alternatives and could also mitigate some of the financial stability concerns that would be associated with securities-backed stablecoins.

Annex I. Details of CBDC Replacement Scenarios

Baseline Scenario

We start with a baseline scenario, using illustrative values (in an arbitrary unit) of balance sheet components of the consolidated banking sector and of the central bank before the issuance of the CBDC. We consider a hypothetical country with an arbitrary unit, taking elements from euro area, Japanese, and US data to construct bank balance sheets.

The size of the balance sheet of the consolidated banking sector is set at 10,000. *Loans* represent 60 percent of total assets, *government bonds* 15 percent, *reserves* 1.4 percent, and the category o*thers* 23.6 percent. Government bonds are distinguished from other securities, since they are assumed to be the only securities that can be used as collateral by banks when borrowing from the central bank.[1] Banks are subject to minimum reserve requirements, set at 2 percent of *deposits*.[2] On the liability side, deposits are the primary and cheapest funding source, representing 70 percent of total liabilities. *Lending* from the central bank represent 7.5 percent of the liabilities, *debt issued*, and *capital* represent 5 percent each, and *other short-term liabilities* 12.5 percent [3]

The balance sheet of the central bank represents one fifth of the balance sheet of the banking sector. Half of the central bank's assets consist of *securities*, while lending to commercial banks and *others* represent 37.5 percent and 12.5 percent, respectively. Of the central bank's liabilities, *cash* accounts for half, with commercial bank reserves and *other liabilities,* such as CB issued bonds making up another 7 percent and 43 percent.

Table 1. The Balance Sheet in the Baseline Scenario (without CBDC)

Consolidated banks				**Central Bank**			
Assets		**Liabilities**		**Assets**		**Liabilities**	
Loans	6,000	Deposits	7,000	Lending	750	Cash	1,000
GB (gov. bond)	1,500	CB lending	750	Securities	1,000	Reserves	140
Reserves (140 required)	140	Debt issued	500	Others	250	Others	860
Others	2,360	Other ST	1,250				
		Capital	500				
Total	**10,000**	**Total**	**10,000**	**Total**	**2,000**	**Total**	**2,000**

SOURCE: Authors.

Scenario 0: Cash-like CBDC

In this scenario, the distribution of the CBDC involves an exchange for cash, in part since the CBDC is assumed to have attributes that make it more of a substitute for cash. When such a CBDC mainly drains cash

[1] In practice, some central banks accept corporate bonds and high-rated loans as collateral. We assume here that only government bonds can be used as collateral for the sake of simplicity.

[2] The reserve requirement is currently 1 percent in the euro area, and zero percent in the US.

[3] As a reference, the deposit share in total liabilities of banking sector in US and EU (end of 2021) is 79 percent and 62 percent, respectively.

from the economy, the impact on deposits will be very limited.[4] For concreteness in the worked example, CBDC issuance is assumed to be 400, representing 5 percent of the value of money (the total amount of deposits and cash) used by households. This calibration is based on Li (2022), who estimates that cash-like CBDC – no remuneration, no cost, transactions anonymity – replaces around 4 percent of households' liquid assets.[5] In this scenario, there are no material implications for the banking system, since both CBDC and cash are direct liabilities of the central bank. To illustrate this, 400 of cash is replaced by 400 of CBDC within the central bank's balance sheet, while deposits are unaffected.

Table 2. The Balance Sheets in Scenario 0 (cash-like CBDC)

Consolidated banks				Central bank			
Assets		Liabilities		Assets		Liabilities	
Loans	6,000	Deposits	7,000	Lending	750	Cash	600 (-400)
GB (gov. bond)	1,500	CB lending	750	Securities	1,000	Reserves	140
Reserves (required 140)	140	Debt issued	500	Others	250	Others	860
Others	2,360	Other ST	1,250			CBDC	400 (+400)
		Capital	500				
Total	**10,000**	**Total**	**10,000**	**Total**	**2,000**	**Total**	**2,000**

SOURCE: Authors' calculations.

Scenario 1: CBDC replaces deposits, but banks possess excess reserves

In this scenario, the CBDC replaces deposits, rather than cash in household's balance sheets, but banks are assumed to possess excess reserves. This corresponds to the situation currently observed in several advanced economies following asset purchase programs initiated in response to the GFC and the COVID-19 pandemic. To illustrate this, we assume that reserves amount to 600 to start with, while the required reserves continue to be 2 per cent of deposits, amounting to 148, initially. The drain on deposits leads to a drawdown of excess reserves, as banks use reserves to obtain the CBDC from the central bank to enable households to purchase CBDC with their deposits. As shown in Table 4 of the main text, in this scenario the LCR, and the NSFR are virtually unchanged, since excess reserves can absorb the full amount of CBDC issued.

Table 3. The Balance Sheets in Scenario 1 (excess reserves)

Consolidated banks				Central bank			
Assets		Liabilities		Assets		Liabilities	
Loans	6,000	Deposits (initially 7,400)	7,000 (-400)	Lending	810	Cash	1,000
GB (gov. bond)	1,500	CB lending	810	Securities	1,400	Reserves (initially 600)	200 (-400)
Reserves (initially 600; required 140)	200 (-400)	Debt issued	500	Others	250	Others	860
Others	2,360	Other ST	1,250			CBDC	400 (+400)
		Capital	500				
Total	**10,060**	**Total**	**10,060**	**Total**	**2,460**	**Total**	**2,460**

SOURCE: Authors' calculations.

[4] For example, certain CBDC design features, such as ensuring anonymity of transaction or no transaction costs might encourage the replacement of cash. However, in reality CBDCs are likely to replace both cash and deposits to a certain extent resulting in combinations of the different scenarios considered.

[5] Also, Bijlsma et al. (2024) investigate the factors affecting the demand of CBDC using the survey conducted in Netherlands.

Scenario 2-A: CBDC replaces deposits, no excess reserves, banks possess enough collateral

In this scenario, CBDC is assumed to replace deposits by 750, increasing to around 9 percent its share in households' liquid assets, the sum of cash and deposits. Li (2022) estimates that when a "baseline design" CBDC is issued, total CBDC holdings could represent between 4 and 52 percent of households' liquid assets.[6] Thus, this scenario corresponds to a case where CBDC replacement is larger compared to Scenario 0 and Scenario 1, but remains relatively low, with CBDC used mostly to make payments.

Banks only possess minimum required reserves. However, they hold sufficient government bonds as liquid assets that can be pledged with the central bank to obtain the additional reserves needed to acquire the CBDC through a loan from the central bank. In particular, banks can compensate the decrease in the deposits by increasing their borrowing from the central bank as in Brunnermeier and Niepelt (2019), by using their holdings of government bonds as collateral (it is assumed that central banks do not apply any haircut when accepting the government bonds as collateral). In this scenario, banks therefore do not have to reduce their assets or increase their wholesale funding.

Table 4 below summarizes the balance sheet changes. The reduction of the deposits of 750 is compensated by banks through central bank borrowing. The right-hand side of Table 3 shows the central bank's balance sheet, highlighting that the increase in the asset side (lending to banks) balances out the increase in CBDC issuance of the liability side. The reserve requirement is assumed to be 2 percent of deposits; required reserves fall due to the reduction in deposits. However, we assume that banks continue to hold the same amount of reserves as in the baseline scenario because they face a more volatile demand of deposits, as pointed out in Federal Reserve (2021).

As shown in Table 4 of the main text, the reduction in deposits has financial stability implications through a drop in LCR, and the NSFR, as well as a reduction in profits. Specifically, since the central bank lending operation is assumed short term, the LCR and NSFR decrease below their regulatory minima of 100 percent. Moreover, the substitution of some deposits, the cheapest funding source, by central bank borrowing is weighing on the banking sector's profitability. As a result, some banks may choose to shrink some lending or to increase their lending rate in the longer run, as we elaborate on in Scenario 4, below.

Table 4. The Balance Sheets in Scenario 2-A (central bank lending)

Consolidated banks				Central bank			
Assets		**Liabilities**		**Assets**		**Liabilities**	
Loans	6,000	Deposits	6,250 (-750)	Lending	1,500 (+750)	Cash	1,000
GB (gov. bond)	1,500	CB lending	1,500 (+750)	Securities	1,000	Reserves	140
Reserves (required 125)	140	Debt issued	500	Others	250	Others	860
Others	2,360	Other ST	1,250			CBDC	750 (+750)
		Capital	500				
Total	**10,000**	**Total**	**10,000**	**Total**	**2,750**	**Total**	**2,750**

SOURCE: Authors' calculations.

[6] A "baseline design CBDC" is defined as a non-interest-bearing CBDC which is unbundled with bank services and achieves 70 percent of cash budgeting usefulness and anonymity.

Scenario 2-B: Commercial bank balance sheets expand

In this scenario, CBDC replaces deposits to a greater extent than in Scenario 2-A. Specifically, due to an attractive design of CBDC, such as a positive interest rate with generous or no limits on holdings, it is assumed that 1200 of deposits are replaced by the CBDC, representing 15 percent of households' liquid assets. Banks do not hold government bonds in amounts sufficient to access central bank lending or other central bank market operations to generate the necessary increase in reserves. In this scenario, banks therefore increase other liabilities in order to offset the decrease in reserves.

In response to the drop in deposits, we here assume that banks like to increase their borrowing from the central bank, and that this also can happen to some extent. However, such borrowing is limited since banks lack enough government bonds that would be accepted by the central bank as collateral. Banks therefore first increase their wholesale funding from NBFI to purchase government bonds from them, and then use these bonds to borrow from the central bank.

Thus, commercial banks' balance sheets expand, and the LR declines (Table 4 of the main text) because of the increased use of wholesale funding by banks to purchase government bonds, which in turn, is used to borrow from the central bank. Since the central bank lending is short term, the LCR and NSFR fall below their regulatory minima of 100 percent. Moreover, the partial substitution of deposits (the cheapest funding source) by wholesale funding and by central bank borrowing lowers the banking sector's profitability.

Table 5. The Balance Sheets in Scenario 2-B (balance sheets expansion)

Consolidated banks				Central bank			
Assets		**Liabilities**		**Assets**		**Liabilities**	
Loans	6,000	Deposits	5,800 (-1,200)	Lending	1,950 (+1,200)	Cash	1,000
GB (gov. bond)	2,000 (+500)	CB lending	1,950 (+1,200)	Securities	1,000	Reserves	140
Reserves (require 116)	140	Debt issued	500	Others	250	Others	860
Others	2,360	Other ST	1,750 (+500)			CBDC	1,200
		Capital	500				
Total	**10,500**	**Total**	**10,500**	**Total**	**3,200**	**Total**	**3,200**

SOURCE: Authors' calculations.

Scenario 3-A: Banks' balance sheet unchanged, higher wholesale funding

In response to the drop in deposits, rather than seeking to borrow more from the central bank, banks here increase their wholesale funding, keeping the size of their balance sheet unchanged.[7] Wholesale funding is assumed to be offered by NBFIs, rather than other banks, since all banks in the system face a fall in deposits and do not have resources to offer funding. This rise in wholesale funding is facilitated by the central bank purchasing additional government bonds from the NBFI sector. The NBFIs in turn lend the reserves received in those operations to the commercial banking sector (see Box 1 for details).

In this scenario, banks experience a reduction in the deposits, and compensate half of this drop by short-term wholesale funding (such as repos), and half by long-term funding such as issuing debt. As shown in Table 4 of the main text, by using some long-term funding, banks experience an increase in the LCR to 1.12, which is above the regulatory minimum of 100 percent. The NSFR stands at 0.95, which is only slightly below

[7] In this scenario, NBFIs sell government bonds to central banks to offset the reduction in total amount of reserves. The details of the balance sheet changes in financial institutions as well as in the central bank are described in Box 1.

the regulatory minimum of 100 percent and above the value of Scenario 2-B (0.92). However, due to the use of more costly long-term financing (banks' issued debt is remunerated at 4 percent, twice as much as the cost of central bank lending, due to a longer maturity), banks' profitability worsens significantly, and the ROE drops to 0.9 percent.

Table 6. The Balance Sheet in Scenario 3-A (increase in wholesale funding)

Consolidated banks				Central bank			
Assets		Liabilities		Assets		Liabilities	
Loans	6,000	Deposits	5,800 (-1,200)	Lending	750	Cash	1,000
GB (gov. bond)	1,500	CB lending	750	Securities	2,200 (+1,200)	Reserves	140
Reserves (require 116)	140	Debt issued	1,100 (+600)	Others	250	Others	860
Others	2,360	Other ST	1,850 (+600)			CBDC	1,200 (+1,200)
		Capital	500				
Total	**10,000**	**Total**	**10,000**	**Total**	**3,200**	**Total**	**3,200**

SOURCE: Authors' calculations.

Scenario 3-B: Foreign borrowing

In this scenario, domestic NBFIs are not willing or able to provide wholesale funding to the banking sector, or to sell their government bond holding to the central bank. This could, for example, be the case in financially less developed economies, where NBFIs are typically small and do not have the capacity to lend money to the banking sector. As a result, banks rely on foreign borrowing, exclusively in the form of short-term funding.

The lenders could be foreign NBFIs or foreign banks. In either case, it is assumed that foreign financial institutions are not willing to provide long-term lending in local currency. This means that the funding received from foreign institutions is short-term. It is further assumed to be denominated in a major foreign currency, such as the dollar or euro, as foreign banks are reluctant to take currency risk. Thus, compared to Scenario 3-A, a currency mismatch arises in the banking sector in addition to a maturity mismatch. The resulting risks are discussed in more detail in the main text.

On the part of the central bank, since banks' reserves are insufficient to purchase the CBDC, the issuance of the CBDC requires it to expand its balance sheet, and it increases its holdings of foreign government bonds in this scenario. The central bank purchases foreign currency from a domestic bank, which receives domestic currency in exchange for the foreign currency and uses the higher reserves to satisfy the move from deposits to CBDC. However, the domestic bank needs to borrow the foreign currency from a large international bank and increases its short-term wholesale funding in foreign currency. Box 1 summarizes the balance sheet changes of this Scenario 3-B, highlighting the difference between the scenarios.

Table 7. The Balance Sheet in Scenario 3-B (foreign borrowing)

Consolidated banks				Central bank			
Assets		Liabilities		Assets		Liabilities	
Loans	6,000	Deposits	5,800 (-1,200)	Lending	750	Cash	1,000
GB (gov. bond)	1,500	CB lending	750	Securities	2,200 (+1,200)	Reserves	140
Reserves (require 116)	140	Debt issued	500	Others	250	Others	860
Others	2,360	Other ST	2,450 (+1,200)			CBDC	1,200 (+1,200)
		Capital	500				
Total	**10,000**	**Total**	**10,000**	**Total**	**3,200**	**Total**	**3,200**

SOURCE: Authors' calculations .

Scenario 4-A: Loans shrink

In Scenario 4, we allow second-round effects after the initial set of transactions that are required for the issuance of the CBDC to take place. The central bank is assumed to target a relatively large issue size of 1200 (as in Scenario 3). The initial set of transactions generate the reserves needed to accomplish the issuance of that volume: there is a loan provided by the central bank to the commercial banking system, collateralized by government securities, as well as an outright purchase of government securities by the central bank that results in banks receiving wholesale funding from the NBFI sector.

Since these transactions result in high funding costs on a substantial part of the commercial banks' balance sheets, there is a transmission to higher loan rates on loans. Specifically, in this scenario we assume that the banks fully pass through the increase in funding costs due to the increase in expensive central bank lending to the loan rate, which increases by 0.3 percent. This amounts to a shift in of the loan supply curve offered by the banking system which meets loan demand at a reduced volume. That is, loan demand is lower at the higher interest rates now demanded by the banking system. This leads to provision of credit to shrink and allows the banking system to retire some of the expensive wholesale funding. The mechanism of this change in the balance sheet of banking sector as well as the central banks is described further in the final table of Box 1. As a result, although banks rely on central bank financing (+960) to compensate for the drop in deposits (-1200), this substitution is only partial so that their balance sheet is shrinking, as shown in Table 7.

As reported in Table 4 of the main text, the LR increases due to the reduction in the size of banks' balance sheets, the LCR declines below its regulatory minimum due to the reduction in deposits and the increase in central bank lending, as this leads to a decrease in the amount in unencumbered HQLA. The NSFR also decreases as the reliance on unstable central bank lending has expanded. The ROE decreases in part because the size of the balance sheet, including loans, is reduced.

Table 8. The Balance Sheet in Scenario 4-A (loans shrink)

Consolidated banks				Central bank			
Assets		Liabilities		Assets		Liabilities	
Loans	5,760 (-240)	Deposits	5,800 (-1,200)	Lending	1,710 (+960)	Cash	1,000
GB (gov. bond)	1,500	CB lending	1,710 (+960)	Securities	1,240 (+240)	Reserves	140
Reserves (require 116)	140	Debt issued	500	Others	250	Others	860
Others	2,360	Other ST	1,250			CBDC	1,200 (+1,200)
		Capital	500				
Total	**9,760**	**Total**	**9,760**	**Total**	**3,200**	**Total**	**3,200**

SOURCE: Authors' calculations. .

Scenario 4-B: Loans shrink together with the change in interest rates

In this scenario, loans shrink, similar to Scenario 4-A, but we also adjust the interest rates in addition to the balance sheet changes.[8] The CBDC issuance is 1200, the same amount as in Scenario 4-A. We assume that banks will replace some of the lost deposit funding with central bank funding and that the central bank will purchase securities from the NBFI sector, again as in Scenario 4-A. However, in this scenario we assume that the banks will increase the deposit rate by 0.5 percent to prevent the deposit outflow, in response to a CBDC issuance. We also assume that banks are not able to prevent the issuance of as much as 1200 of the CBDC.

The increase in funding costs due to the rise in deposit rate and increase in the share of expensive central bank reduces bank profits and will push banks to raise their lending rates. Compared to Scenario 4-A where the banks pass through the entire increase in the cost to lending rates, we here assume that banks only pass through 75 percent of the increase in funding costs. This reduces somewhat the impact on loans, but results in a less profitable banking sector. Overall though, as funding costs increase on almost all bank liabilities, banks will reduce their credit supply by more than in Scenario 4-A, as lending here decreases by 40 percent of the CBDC issued.

Table 9. The Balance Sheet in Scenario 4-B (Loans shrink)

Consolidated banks				Central bank			
Assets		Liabilities		Assets		Liabilities	
Loans	5,520 (-480)	Deposits	5,800 (-1,200)	Lending	1,470 (+720)	Cash	1,000
GB (gov. bond)	1,500	CB lending	1,470 (+720)	Securities	1,480 (+480)	Reserves	140
Reserves (require 116)	140	Debt issued	500	Others	250	Others	860
Others	2,360	Other ST	1,250			CBDC	1,200 (+1,200)
		Capital	500				
Total	**9,520**	**Total**	**9,520**	**Total**	**3,200**	**Total**	**3,200**

SOURCE: Authors' calculations.

[8] In the quantification in the previous literature (Whited et al.,2023) the loans are reduced about 40 percent of the CBDC issuance.

Box 1. Changes in Balance Sheets Following CBDC Issuance Through Reserves and Open Market Operations

When households increase their cash holdings by withdrawing deposits, the amount of reserves declines because banks use reserves to purchase banknotes. When households purchase CBDC by reducing deposits, the change in banks' balance sheets is very similar to what happens when households increase their cash holdings, since CBDC is also a direct liability of the central bank. The changes in the balance sheets of the central bank and of the banks are summarized in Table A-1.

Table A-1. Changes in balance sheet in the issuance of CBDC

	Assets	Liabilities
Central bank (CB)		Reserves ↓ CBDC ↑
Banks	Reserves ↓	Deposits ↓
Households (HH)	Deposits ↓ CBDC ↑	

As suggested by Table A-1, the issuance of the CBDC leads in the first instance to a reduction in the amount of reserves banks hold on deposit with the central bank. This means however that banks demand for reserves is increasing, all else equal, putting upward pressure on interbank rates. In particular, banks may demand more reserves to satisfy reserve requirements when they only hold minimum required reserves prior to the introduction of CBDC.

Unless the central bank has room to adjust downward the reserve requirement, or the central bank operates a floor system, where the central bank supplies abundant reserves at its desired interest rate (see Brandão-Marques and Ratnovski (2024)), and the demand for reserves is satiated even after the issuance of the CBDC, the central bank is likely to use open market operations to increase the supply of reserves in response to banks' higher demand for reserves. Otherwise, the interbank rate would rise since banks would seek to obtain liquidity on the interbank market to maintain their reserve requirements or satisfy the additional demand for reserves.

Open market operations can be temporary or permanent. Temporary operations include central bank lending guaranteed by collateral, in which banks repay the loan after a certain period. Permanent operations include asset purchases, such as government bonds, and imply a permanent increase in the total amount of reserves. The balance sheet changes following the temporary and permanent central bank's operations are summarized in Table A-2 and A-3, respectively.

Table A-2. Changes in balance sheet following central bank lending

	Assets	Liabilities
CB	CB lending ↑	Reserves ↑
Banks	Reserves ↑	CB lending ↑

Table A-3. Changes in balance sheet following asset purchases by the central bank

	Assets	Liabilities
CB	Government bonds (GB) ↑	Reserves ↑
Banks	Reserves ↑ GB ↓	

Box 1. Changes in Balance Sheets Following CBDC Issuance Through Reserves and Open Market Operations (continued)

Table A-4 presents the resulting aggregate balance sheet changes following central bank lending when households purchase CBDC. This corresponds to Scenario 2-A, where banks have sufficient government bonds that can be offered as collateral to support the borrowing from the central bank. The size of the banking sector's balance sheet does not change, while the size of the central bank's balance sheet expands due to the issuance of CBDC.

Table A-4. Changes in balance sheets following the issuance of CBDC (CB lending case)

	Assets	Liabilities
CB	CB lending ↑	CBDC ↑
Banks		Deposits ↓ CB lending ↑
HH	Deposits ↓ CBDC ↑	

Table A-5 illustrates the changes in the balance sheet when commercial banks expand their balance sheets. In this scenario, banks augment their wholesale funding from NBFIs to purchase additional government bonds, as they must hold sufficient collateral to access central bank lending. Consequently, the size of the banking sector's balance sheet increases, leading to a reduction in the leverage ratio, which is a key characteristic of Scenario 2-B.

Table A-5. Changes in balance sheets when commercial banks expand their balance sheet

	Assets	Liabilities
CB	CB lending ↑	CBDC ↑
Banks	GB ↑	Deposits ↓ CB lending ↑ Wholesale funding ↑
NBFI	GB ↓ Wholesale funding ↑	
HH	Deposits ↓ CBDC ↑	

In the case of central bank asset purchase operations, the banks sell their government bonds to the central bank. If banks do not hold enough government bonds, NBFI can sell government bonds to the central bank instead, and then lend the additional reserves to the commercial banking sector. Specifically, in the first step, an NBFI holding reserve accounts sells government bonds to the central bank and increases the reserve holdings.[1] In the second step, this NBFI lends these additional reserves to the commercial banking sector by wholesale funding. Table A-6 describes the overall change of the balance sheet, corresponding to Scenario 3-A.

[1] Typically, large investment banks hold reserve accounts with the central bank in advanced economies. However, the overall balance sheet change in this scenario described in Table A-5 also holds even if NBFIs do not have reserve accounts. For example, when pension funds would like to sell their government bonds to the central bank, they can settle this transaction through custodian banks that hold a reserve account.

Box 1. Changes in Balance Sheets Following CBDC Issuance Through Reserves and Open Market Operations (continued)

Table A-6. Changes in balance sheets following the issuance of CBDC (asset purchase case)

	Assets	Liabilities
CB	GB ↑	CBDC ↑
Banks		Deposits ↓ Wholesale funding ↑
NBFI	GB ↓ Wholesale lending ↑	
HH	Deposits ↓ CBDC ↑	

NOTE: In this scenario, NBFIs sell government bonds to central bank, which neutralize the decrease in total amount of reserves. Banks use wholesale funding from NBFI to offset the decline in reserves due to the issuance of CBDC.

Table A-7 describes the overall change of the balance sheet when banks increase foreign borrowing, corresponding to Scenario 3-B. This is the case when households replace deposits with CBDC (Table A-1), and banks increase wholesale funding from foreign banks, while the central bank increases the holding of foreign government bonds. Compared to Table A-6, foreign banks, instead of domestic NBFI, sell foreign government bonds to the central bank, and increase the foreign wholesale funding to the commercial banks in this scenario. We assume here that both the foreign bonds and the wholesale funding is denominated in dollar. To effect a change in currency, the central bank would purchase the dollars it needs to buy the dollar bonds from the commercial banks. These banks sell the dollars they have received as a wholesale loan from the foreign entity and receive the local currency reserves from the central bank that are needed to purchase the CBDC.[2]

Table A-7. Changes in balance sheets following the issuance of CBDC (when banks use foreign borrowing)

	Assets	Liabilities
CB	Foreign GB ($) ↑	CBDC ↑
Banks		Deposits ↓ Foreign wholesale funding ($) ↑
Foreign banks	Foreign GB ($) ↓ Foreign wholesale lending ($) ↑	
HH	Deposits ↓ CBDC ↑	

NOTE: In this scenario, banks use foreign borrowing to offset the decline in deposits. The central bank increases the holdings of foreign government bonds, sold by foreign banks. In this table dollar is assumed as foreign currency and denoted as ($). Commercial banks sell dollar to the central bank to purchase local currency, neutralizing the decline in deposits.

[2] Some readers might wonder how the reserves balance out in these transactions since the banks need to offset the reduction in reserves due to the CBDC issuance. In this scenario, the central bank purchases local currency from the commercial banks to buy foreign bonds, which increases the total amount of reserves in the system. This is similar to the transaction in unsterilized FX intervention.

Box 1. Changes in Balance Sheets Following CBDC Issuance Through Reserves and Open Market Operations (concluded)

Table A-8 shows the balance sheet changes when loans shrink, corresponding to Scenario 4. To put this in order, (1) households replace deposits with CBDC, (2) banks reduce reserves and deposits to handover CBDC to households (3) banks sell government bonds to the central bank to offset the decline in reserves, (4) banks increase wholesale funding to purchase government bonds from NBFI (to offset the reduction in government bonds) (5) when loan demand shrinks as a result of higher loan rates, banks lower the wholesale funding on their liability side, offsetting some of the increase in initial wholesale borrowing.

Table A-8. Changes in balance sheets following the issuance of CBDC (loan shrinkage case)

	Assets	Liabilities
CB	GB ↑	CBDC ↑
Banks	Loans ↓	Deposits ↓
HH	Deposits ↓ CBDC ↑	

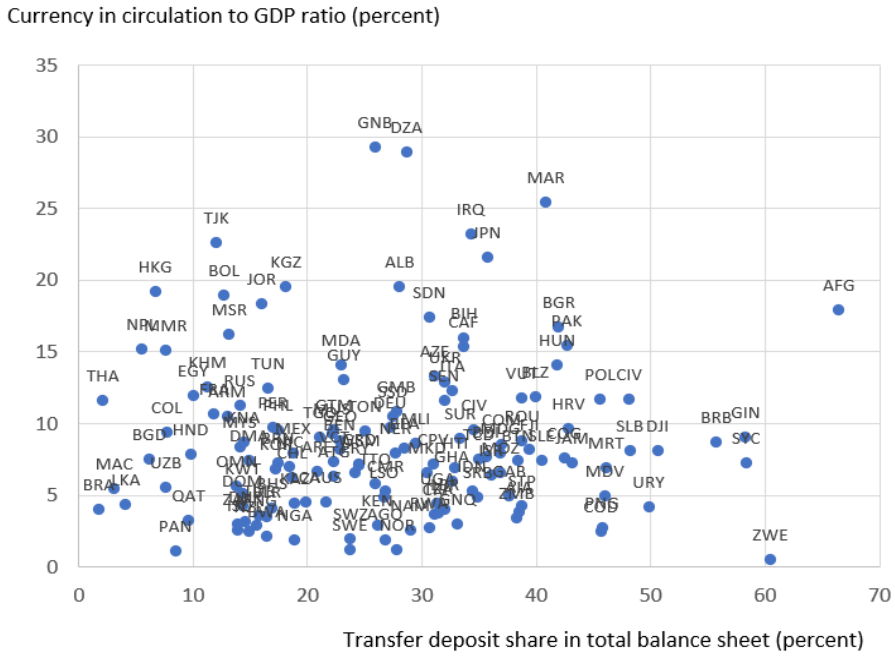
NOTE: In this scenario, in addition to the balance sheet change in Table A-5, banks reduce the loans in the asset side as well as decrease the usage of wholesale funding.

Annex II. Quantitative Indicators

As was draw out in the scenario analysis (Section 3), the change in banking sectors' balance sheets varies across scenarios, as do, accordingly, the associated financial stability implications. Countries are likely to differ significantly in the initial conditions that may determine which of the scenarios is likely to arise. For example, as discussed in Section 3, when financial inclusion is low, the issuance of CBDC may result primarily in a reduction in physical cash-in-circulation, and may then have only mild effects on deposits, limiting adverse effects on the banking sector. Moreover, where the banking sector holds ample reserves, even if there is reduction in deposits, and not just cash, the issuance of CBDC is funded by a drawdown of these reserves, and may then have limited adverse financial stability implications.

As a first illustration of this, Annex Figure 1 shows the cash in circulation (CIC)-to-GDP ratio on the vertical axis and the share of transfer deposits in total liabilities of the banking sector on the horizontal axis. This figure provides an indication of whether CBDC is likely to replace cash (Scenario 0) or replace deposits. CBDCs may be more likely to replace cash in the countries in the upper left region, because for those countries the cash-to-deposit ratio is high. On the other hand, CBDCs are more likely to replace deposits in the countries in the bottom right region. Clearly, however, the ratio of cash to transfer deposits is only indicative, and other elements, such as households' preferences on method of payments as well as CBDC design will ultimately also affect whether CBDC replaces cash or deposits.

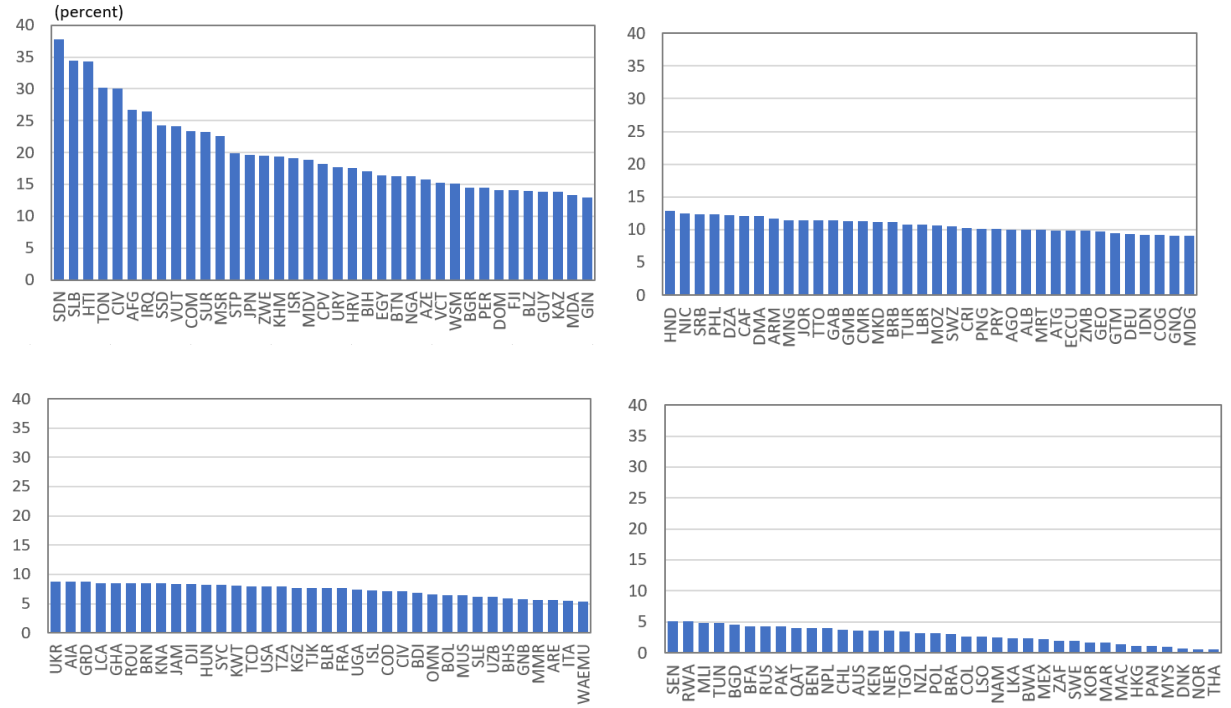
Figure 1. Cash and Deposits Shares



SOURCES: IFS and MFS.
NOTE: 5-year averages (2017–21).

The share of reserves in banks' balance sheets also varies considerably across countries (Annex Figure 2).[1] This share is relevant in assessing whether a given amount of CBDC can be issued in exchange for existing excess reserves (Scenario 1) or whether existing reserves may not be sufficiently abundant for this purpose. Specifically, the banking sector in countries shown on the left side of Annex Figure 2 are more likely to have sufficient excess reserves and could reduce them when the deposits are replaced by CBDC. On the other hand, the banking sectors of the countries towards right of the chart may not hold sufficient reserves in case the amount of CBDC to be issued is large. This implies that banks need to find other funding sources such as central bank lending or wholesale funding, or to reduce their assets.

Figure 2. Shares of Reserves to Total Assets Across Banking Sectors



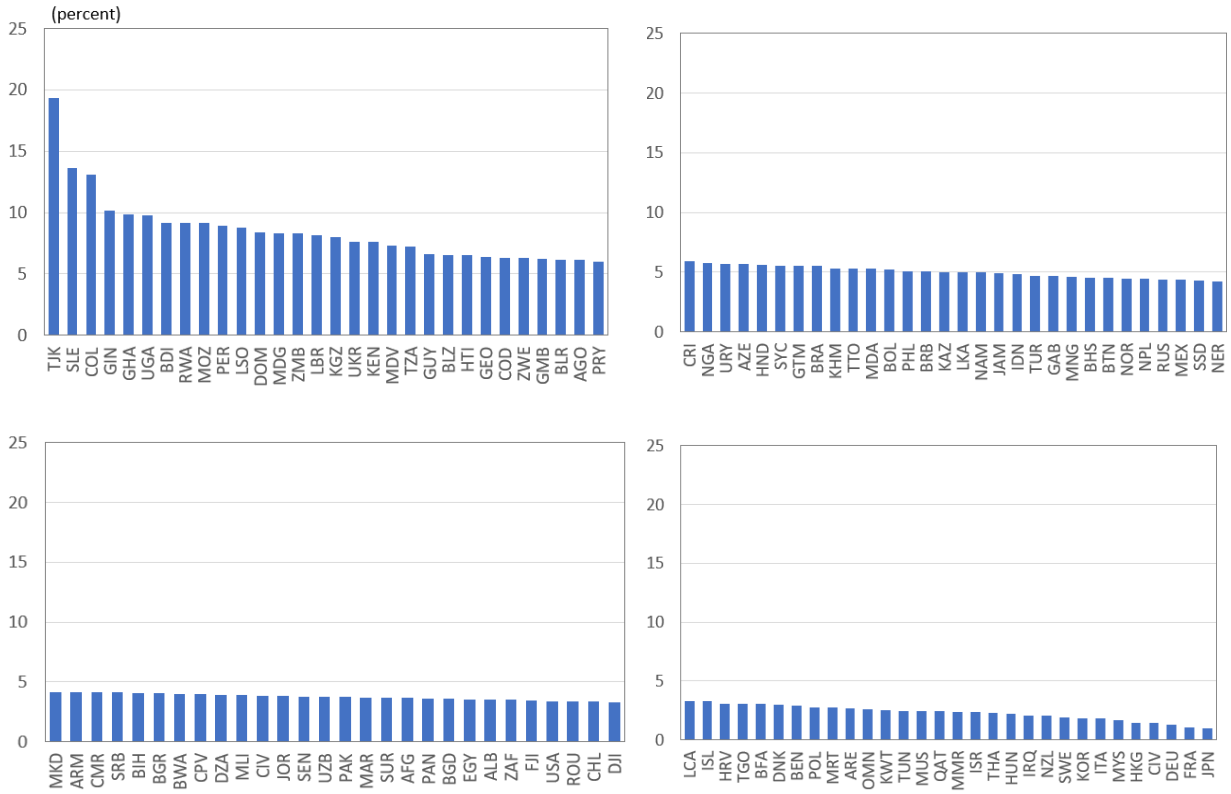
SOURCES: IFS and MFS.
NOTE: 5-year averages (2017–21).

Interest margins in the banking sector also vary substantially across countries, as illustrated in Annex Figure 3. When interest margins are tight, and the banking sector is highly competitive and less profitable, the pass-through to loan rates from a rise in funding cost may be larger, because banks do not have sufficient margin to absorb the growth in expenses in these circumstances. In such cases, when costs increase, the provision of credit to the economy is likely to shrink more sharply, as the supply of loans shifts in. The interest margin can also inform about the likelihood of other financial stability implications form the issuance of CBDC. For instance, the interest margin can also be indicative of risk shifting incentives as profits are squeezed. Some

[1] We use is the reserve share, which does not necessarily highlight excess reserves, since reserve requirements differ across countries (cross-country data comparing these requirements are not readily available). The reserves share is also more informative of whether reserves are sufficient since reserves requirements could be lowered to enable more reserves to be used in the issuance of the CBDC.

banks invest in riskier projects because they cannot otherwise maintain their profits. Other banks, finally, may respond by exiting in such a more competitive environment.

Figure 3. Net interest rate margins of banking sectors across countries



SOURCES: IFS and MFS.
NOTE: 5-year averages (2017–21).

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Working Paper No. WP/2024/226