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The impact of central bank digital currency on central bank profitability, risk-taking and capital

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Contents

Abstract

As digital payments become increasingly popular, many central banks are looking into the issuance of retail central bank digital currency (CBDC) as a new central bank monetary liability in addition to banknotes and commercial bank reserves. CBDC will have broadly the same balance sheet and profit implications as the issuance of banknotes. While the decision to issue CBDC is often thought to likely increase the size of central banks' balance sheets, the net impact of digitalisation on balance sheet size could also be negative, as the number of banknotes in circulation may decline and CBDC's design features could limit its take-up as a store of value. We use scenario analyses to illustrate the key drivers of the impact of CBDC on central bank profitability, with the part of CBDC that does not derive from an exchange of banknotes being an important factor. The financial risk implications of CBDC for central banks can be managed via well-established frameworks and relate primarily to the impact on balance sheet size and asset composition. The paper concludes with a discussion on how the profit and risk channels affect central bank capital.

JEL classification: E58

Keywords: central bank digital currency, central bank capital, financial risk management, seigniorage, digital money

Non-technical summary

This paper analyses how the introduction of CBDC that is available to households (sometimes called “retail CBDC”) may affect a central bank’s balance sheet, profitability, financial risks and capital. The pros and cons of CBDC have been debated extensively since 2016 and the perception has emerged during this time that most central banks will eventually deploy their monetary liabilities not only as digital commercial bank reserves and as physical banknotes, but also in digital form to the general public. In essence, CBDC would preserve the advantages of central bank money in a digital age in which people will use banknotes less and less to make payments. The availability and use of central bank money has served economies and societies well for several centuries. Failure to provide a new form of central bank money that is available to all in a digital age would mean relinquishing a well-tested two-layer monetary system based on the coexistence between central and commercial bank money.

The effects of the issuance of CBDC on central banks’ balance sheets and profitability will depend on its key features, which are design parameters set by the central bank. Apart from its general attractiveness as a means of payment (in this respect, central banks should do their utmost to make CBDC attractive to use), there are some key design features that will influence the amount of CBDC in circulation. These include remuneration, holding limits, access criteria and features which reduce the incentives for users to stockpile CBDC (such as the ECB’s digital euro “reverse waterfall” functionality that links CBDC with a user’s commercial bank account). Within these constraints, the actual amount of CBDC in circulation will be determined by household demand, just as household demand determines the amount of banknotes in circulation.

The literature on the financial stability implications of CBDC and the related publications of banking associations on this topic tend to assume that central bank balance sheets will expand as a result of future CBDC issuance. However, this seems to be uncertain if we consider the emerging parameter choices of central banks and the declining use of cash as a means of payment. There is further uncertainty surrounding the future size and composition of central banks’ balance sheets because monetary policy needs will evolve and the still sizeable balance sheets seen today, following the pandemic-related quantitative easing measures, may shrink further.

We develop a model to quantify the change in central banks’ net interest income compared with a balance sheet without CBDC. This is then applied for the euro area and the potential introduction of a digital euro under different scenarios. A pure exchange of banknotes for CBDC has no further implications on central banks’ balance sheets, and thus their financial risks, profits and capital. This is different, however, for other exchanges of monetary liabilities (e.g. because CBDC volumes are significant and the amount of banknotes in circulation does not decline much; or CBDC volumes turn out to be small thanks to the design features chosen, but the

decline in banknotes in circulation is significant owing to digitalisation). We review a number of specific scenarios to illustrate the range of possible outcomes for profitability. We find that in a positive interest rate environment, the introduction of CBDC would tend to give rise to higher income for central banks. However, this income might turn out to be relatively modest as a result of the design features to limit CBDC volumes.

The financial risk Implications of CBDC for central banks arise primarily through the amount and composition of the additional assets that match the additional issuance of central bank liabilities. The risk implications can be managed via well-established frameworks and likely be mitigated by measures to limit CBDC take-up. All else being equal, a central bank's financial risks, such as market and credit risk, would increase most significantly if it had to increase the size of its balance sheet via additional outright purchases of long-term assets. However, the effect on its interest rate risk is ambiguous and depends on the interest rate sensitivity of the assets and liabilities that are already on the balance sheet.

The paper concludes with a discussion on how the profit and risk channels affect the actual and desired amount of the central bank's capital and its (more broadly defined) net equity, taking into account accounting and economic differences. If the introduction of CBDC leads to additional income, the central bank can decide whether to use it to increase its financial buffers. It may alternatively distribute the profits to its shareholders (usually the government), in line with the respective local preferences, needs and profit distribution rules.

1 Introduction

Modern central banks are unique from the perspective of their capital for two main reasons. First, their right to issue legal tender in the absence of any convertibility promise, such as a fixed exchange rate regime or other foreign currency liabilities, implies that they are not threatened by illiquidity and financial insolvency. This provides them with additional leeway in their balance sheet structure compared with a company which does not have this privilege.[1] In any case, money holders will not consider a run on a central bank because they know that it has no liquidity issues.[2] Central banks are thus able to operate in an orderly manner and implement monetary policy (e.g. change the level of short-term market interest rates via their money market operations) regardless of temporary fluctuations in their profitability, capital and net equity (see, for example, Bell et al., 2023; ECB, 2023a). Second, central banks are normally structurally profitable because of their exclusive legal right to issue banknotes as unremunerated central bank money while being able to match these with remunerated assets.

Both factors relate to their privilege to issue central bank money. However, the only central bank money issued to the general public up until now has been in the form of banknotes, and banknotes are being used less frequently for payments (ECB, 2022), thereby reducing their demand for transaction purposes. While most of the banknotes in circulation are understood to serve a store of value function (see Zamora-Pérez, 2021; Devigne et al., 2023), the diminishing use of banknotes to make payments could eventually render them less attractive as a store of value.

Central banks' balance sheets stand out for several other reasons: the basic practical function of a central bank is to issue banknotes as legal tender.[3] Thus, its

1 Convertibility of central bank money had been the norm for centuries and only ended in most countries with the demise of the Bretton Woods system. Moreover, many central banks still operate under a fixed exchange rate regime under which they commit to convert their own currency into a foreign currency. In this case, the required level of capital that should suffice to prevent a run on a central bank can be assessed, e.g. using a model such as Bindseil and Lanari (2022), which models asset liquidity in the sense of the ability of a (central) bank to sell assets in the short term without this inflicting fire sale losses which would deplete capital.

2 Users may decide to hold few or no banknotes issued by a central bank if they find such holdings unattractive and associated with high opportunity costs, notably forgone investment returns in an environment of high nominal interest rates (e.g. driven by high inflation rates). If expectations turn negative (e.g. there is a sudden shift to high inflation expectations), then banknote holders may quickly return banknotes and the central bank's balance sheet will shrink. The liquidity deficit of the banking system vis-à-vis the central bank would decrease, and ultimately banks would be in a liquidity surplus and hold excess reserves with the central bank. But this still does not threaten the liquidity of a modern central bank with no convertibility promise attached to its money because it will never have to liquidate assets in forced fire sales. The calculus of the banknote holders differs greatly from that observed in a run on the debt of a normal debtor (including a run on a commercial bank) which can default on its convertibility promise.

3 Cash also comprises coins, which are quantitatively much less relevant than banknotes. In December 2023 there were €1,567.2 billion in banknotes and €33.5 billion in coins denominated in euro in circulation, as reported in the ECB statistics on banknotes and coins circulation. In most euro area countries and in the United States, coins are not a central bank liability because they are issued by the government (usually the treasury). Thus, only the banknotes in circulation are on the central bank balance sheet, while the coins in circulation are included in the consolidated public sector balance sheet (which combines the central bank and government balance sheets). In the euro area, the Governing Council of the ECB approves the overall value of the coins to be put into circulation annually, but the euro area countries remain the sole legal issuers of coins (see the ECB Explainer, What is money?, accessed 1 September 2024).

balance sheet originates from the liability side – unlike most other firms' balance sheets. As central banks have no liquidity constraints in their own currency, they have a great deal of leeway in terms of what they can hold on the asset side of their balance sheets, provided their mandates and charters allow them to do so. This is even before they consider lengthening their balance sheets beyond the size determined by their issuance of monetary liabilities. They can use this available leeway for specific income generation purposes, such as covering their operating costs, without impairing their policy functions (including monetary policy functions).

Moreover, the central bank can be seen as a stand-alone entity or as part of the consolidated public sector balance sheet from an income and risk-taking perspective. Both approaches should always be considered conceptually to establish whether some conclusions only hold under one of the two, and what this may suggest.

Finally, it is worth noting that in terms of structural central bank profitability, there is only one problematic monetary policy outcome, i.e. a permanent deflationary tendency in which monetary policy interest rates become asphyxiated at zero or even slightly negative levels. The average yield of central bank assets will then move towards zero and ultimately no seigniorage income will be generated, not even to cover operating costs. From this perspective, the recently observed central bank losses relating to reflation after years of lowflation or deflation can also be seen as a sign of a successful escape from the zero lower bound.[4]

In this paper, we focus on how the introduction of CBDC may affect a central bank's balance sheet, profitability, risks, capital and net equity. We do not review the general literature on the relevance of central bank profits and capital (see e.g. Bindseil et al., 2004; Archer and Moser-Boehm, 2013; Goncharov et al., 2023; Stella, 1997; Wessels and Broeders, 2022; Broeders et al., 2024). This focus on the effects on central banks distinguishes our paper from other papers on CBDC (e.g. Bindseil, 2020; Lambert et al., 2024), in which the financial stability implications of CBDC and its effects on commercial bank balance sheets, are the centre of attention. Throughout this paper, the term "CBDC" refers exclusively to CBDC that is available to households (i.e. "retail CBDC").[5]

Section 2 looks at the reasons why central banks issue CBDC and the announcements made so far by those that are at an advanced stage of this process with regard to its design features. These aspects are both crucial for the rest of the paper, as they have profound implications on the future scenarios for total central bank money in circulation and thus their balance sheet length, profitability and risk-taking. Section 3 looks at the impact of CBDC on central bank profitability, using a

4 The literature on central bank solvency and the mechanisms for safeguarding central bank independence discusses potential problems in the other direction: it is reviewed in ECB (2021), focusing on the ways to prevent central banks from risking failure to achieve their monetary policy objectives because of their financial losses and the subsequent lack of fiscal transfers for their recapitalisation. Broeders et al. (2024) discuss this topic in view of the losses recently faced by several major central banks.

5 Central banks and market participants are also discussing the potential introduction of "wholesale CBDC" as tokenised assets to settle transactions between financial institutions in new ways; the balance sheet implications of wholesale CBDC are ultimately equivalent to the existing (digital) deposits of banks with central banks ("reserves") and outside the scope of this paper.

scenario analysis for the Eurosystem as an example. Sections 4 and 5 elaborate on financial risk and capital implications respectively. Section 6 concludes.

2 CBDC: a future monetary liability of central banks

2.1 The "endogeneity" of the CBDC issuance decision and emerging CBDC design features

The pros and cons of CBDC have been debated extensively since 2016 and the perception has emerged during this time that most central banks will also eventually deploy their monetary liabilities in digital form to the general public. In essence, CBDC would preserve the advantages of central bank money in a digital age in which people will use banknotes less and less to make payments. The availability and use of central bank money has served economies and societies well for several centuries. Failure to provide a new form of central bank money that is available to all in a digital age would mean relinquishing a well-tested two-layer monetary system based on the coexistence between central and commercial bank money.

There are several key advantages to preserving the availability of central bank money in a digital age. It would ensure (i) the continued availability of a risk-free medium of settlement; (ii) the continuity of the convertibility promise defining commercial bank money, which is essentially a promise to convert a claim into central bank money at sight; (iii) the availability of a digital means of payment for citizens designed for the public good; and (iv) the availability and usability of central bank money raises competition in an industry with network effects and thus typically a predominance of few players, who will unavoidably try to abuse their market power. Furthermore, CBDC strengthens strategic sovereignty if the dominant private players in the payment markets are foreign-owned companies. Money and payments are a function of universal importance for a society built on the division of labour or, as argued by Simmel (1900), are even at the very core of modern society. Therefore, ensuring the continued availability of an effective form of public money in a digital age appears to be an obvious choice.

While a central bank's decision to issue CBDC will certainly affect its balance sheet, profitability, risk-taking and capital, it should be noted that such a decision would be endogenous to the general transformation of societal habits surrounding the holding and use of money. Furthermore, these changes will have a profound impact on central banks' balance sheets – in an ever more digitalised society, the use of physical cash is likely to decrease, implying an eventual decline in the circulation of banknotes. This, in turn, could reduce their balance sheet size, seigniorage income[6] and profitability. In this context, the decision to issue CBDC appears to be a means to preserve, i.e. stabilise, the role of central bank money, compared with an alternative scenario in which the role of central bank money diminishes as the use of

[6] The term "seigniorage" is not uniquely defined in the literature. In general, and in this paper, seigniorage refers to the revenue from money creation. Broader definitions equate seigniorage with central bank profits. Narrower definitions refer to seigniorage as profit from the creation of banknotes (see, for example, "What is seigniorage?", ECB Explainer, 7 April 2017).

banknotes declines. In the second scenario, the central bank would not only discontinue a large part of its services to society, with possible adverse effects on the perception of money among the general public, but it would also see its balance sheet size, seigniorage and profitability shrink.

The effects of the issuance of CBDC on central banks' balance sheets and profitability will depend on its key features, which are design parameters set by the central bank. Apart from its general attractiveness as a means of payment (in this respect, central banks should do their utmost to make CBDC attractive to use), there are some key design features that will influence the amount of CBDC in circulation.

- **Remuneration**: CBDC is potentially a highly liquid and safe form of investment. If, in addition, it were to exhibit rates of return similar to private forms of money or money substitutes (in particular, savings and term deposits, money market funds or high rated short-term government debt instruments), then large flows of investment into CBDC would be likely to occur. For this reason – and also to emphasise that it has been conceived primarily as a means of payment and not as a store of value – some central banks that have already started to offer CBDC (e.g. the People's Bank of China or the Reserve Bank of India), or that have published their potential design choices (e.g. the ECB or the Bank of England), have all set a zero remuneration rate, making CBDC similar to banknotes in this respect.

- **Limits**: as market interest rates can fall to low levels and go down to zero (or even turn negative), central banks do not consider that a zero remuneration rate is sufficient to prevent CBDC from becoming a large-scale store of value, which could increase the monetary base and the length of the central bank's balance sheet, with potential implications for the economy and financial stability. Therefore, all central banks that have announced CBDC design features have also announced individual limits on CBDC holdings. The ECB, for example, has mentioned a limit of €3,000 per domestic citizen.

- **Access criteria**: while access to banknotes cannot be constrained, central banks can limit access to CBDC. For the time being, central banks seem to be planning to limit holdings of CBDC, at least initially, to domestic natural persons. This implies that non-residents and both financial and non-financial corporates would in principle be excluded and the overall amount of CBDC in circulation would be reduced (merchants would convert incoming CBDC payments into commercial bank money,[7] cross-border e-commerce should eventually be possible and incoming travellers should still be able to pay with CBDC using a temporary access solution). This eliminates significant categories of banknote holders. For example, Zamora-Pérez (2021) and Devigne et al., (2023) suggest that around 40% of euro banknotes are held abroad. During the period of low

[7] This scenario is indeed foreseen for the digital euro, where, for merchants, all incoming payments are immediately converted into commercial bank money.

interest rates in the euro area, some banks and corporates also hoarded banknotes to circumvent the ECB's negative interest rate policies.[8]

- **Features that reduce incentives or even eliminate the necessity to hold a positive CBDC balance**: many retail payment instruments, such as credit cards, debit cards or PayPal, do not require users to hold separate balances. Instead, the instrument debits the account holder's commercial bank account and bridges the time between the payment and the debit using a temporary credit. Some central banks that are designing CBDC have announced similar features, which also remove the necessity to hold balances in advance. The ECB, for example, has announced that it foresees an option where users will be able to activate a "reverse waterfall" process, so that if there is an insufficient digital euro balance for a specific payment, an instantaneous debit will be made from the user's bank account to increase this balance (for the missing amount) and thus allow the payment to go through. As described in ECB (2023b, p. 14): "Users would not need to prefund a digital euro account before making payments. If there are insufficient funds in the digital euro account, the shortfall could be transferred immediately." It calls this the "reverse waterfall" functionality.

The actual amount of CBDC in circulation will be determined by household demand, just as household demand determines the amount of banknotes in circulation. Both banknotes and CBDC are thus "autonomous factors" in the demand for central bank liquidity that the central bank needs to accommodate.

The literature on the financial stability implications of CBDC and the related publications of banking associations on this topic tend to assume that central bank balance sheets will expand as a result of future CBDC issuance. However, this seems to be uncertain if we consider the aforementioned emerging parameter choices of central banks and the declining use of cash as a means of payment (see ECB, 2022), which will likely continue. Despite the issuance of CBDC, the combination of the key design features listed above could also lead to a decrease in the overall size of central bank monetary liabilities over the coming decades, even if the use of central bank money as a means of payment is sustained.

Beyond its impact on the expected demand for CBDC, the first of these key parameters – the remuneration of CBDC – also directly affects the seigniorage income. The term "seigniorage" refers to the revenue from money creation and is not uniquely defined in the literature. According to a broader definition, and as applied in this paper, seigniorage income is essentially equal to the volume of monetary liabilities (banknotes, commercial bank deposits or "reserves" held with the central bank and CBDC), which are matched by a corresponding volume of monetary policy assets, multiplied by the difference between the average remuneration of these assets and liabilities.[9] The non-remuneration of CBDC makes it equivalent to

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8 Euro area commercial banks' monthly stocks of vault cash roughly doubled from around €50 billion to €100 billion between 2015 and 2022, before falling rapidly to €60 billion after the ECB started raising its key interest rates in the summer of 2022 (see, for example, Devigne et al., 2023).

9 Narrower definitions of seigniorage focus on profit from the creation of banknotes (see, for example, "What is seigniorage?" ECB Explainer, 7 April 2017) (accessed 1 September 2024).

banknotes in terms of its contribution to seigniorage. All else being equal, any positive remuneration of CBDC will reduce its contribution to seigniorage, and thus to central bank profitability, relative to the scenario with zero remuneration. However, a positive remuneration of CBDC might increase its take-up, which would have a compensating impact on seigniorage that would likely be constrained by limits on CBDC holdings.

Last but not least, issuing CBDC is not cost free. As with banknotes, the operating costs would need to be deducted from the gross seigniorage income to determine the net contribution to central bank profits. For example, the costs that the Eurosystem will bear for the digital euro encompass the cost of the core settlement layer of CBDC (the back end; including online and offline payments), the costs relating to establishing and maintaining the payment scheme (as defined by the rulebook), the costs of the digital euro payment application, fraud protection and prevention and the necessary information campaigns and branding. The costs of distributing the digital euro through payment services providers would be compensated by a merchant fee and would therefore not be covered by the central bank.

2.2 Issuance of CBDC and the central bank's balance sheet

CBDC is a new liability item on the central bank's balance sheet. It is created and funded by households exchanging their banknotes[10] or the deposits they hold with commercial banks for CBDC. For commercial banks, an outflow of household deposits will imply either a reduction in the reserves held with the central bank, or additional recourse to central bank credit; alternatively, the central bank may decide to restore previous levels of reserves through purchases of securities. The literature on CBDC commonly acknowledges these basic mechanisms (see, for example, Adalid et al., 2022; Ahnert et al., 2024).

The flow chart in Chart 1 illustrates how the choices made by households, banks and the central bank determine how CBDC issuance affects the central bank's balance sheet. It starts by highlighting that households' holdings of banknotes and deposits will also continue to evolve from today in the absence of CBDC – a reflection of the endogeneity of the CBDC issuance decision discussed above, that can thus be separated from the choices made during the CBDC issuance process.

[10] We do not cover the exchange of coins for CBDC separately in this paper because coins are quantitatively much less relevant than banknotes (see footnote 3 for some euro area data and more information on who issues coins). If coins are issued by the central bank, their exchange for CBDC has the same implications for the central bank's balance sheet as the exchange of banknotes for CBDC. In the more common case where coins are issued by the government, exchanging them for CBDC initially lengthens the central bank's balance sheet because the coins become an additional asset corresponding to the additional CBDC liability. In a second step, the central bank could decide to redeem these coins from the government, thus reducing the amount of government deposits held with the central bank and re-establishing its initial balance sheet size. If the government deposits are unremunerated, the implications for the central bank are then identical to the case of an exchange of banknotes.

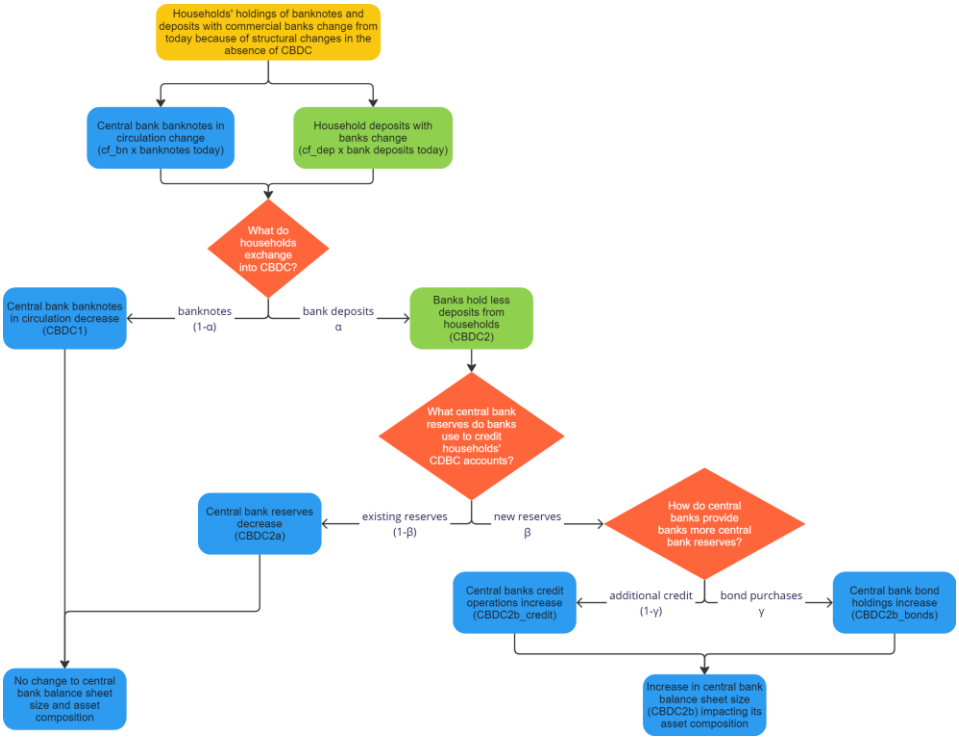
1. Households choose whether to substitute their banknotes (share $1-\alpha$ of total created CBDC) or sight deposits held at banks (share α) with CBDC.

2. Banks then choose whether to use their existing reserves with the central bank (share $1-\beta$ of $CBDC2$ created from sight deposits) or whether they need new reserves (share β) to credit the households' CBDC accounts. The central bank may constrain this choice via its monetary policy implementation framework and according to its monetary policy stance. For example, if the central bank wants to treat CBDC as a fully autonomous factor and maintain the level of excess reserves unchanged for monetary policy reasons, it would create additional reserves (i.e. $\beta = 1$).

3. Central banks go on to choose whether to provide new reserves via bond purchases from banks (share γ of required new reserves $CBDC2b$) or additional collateralised lending to banks (share $1-\gamma$).

Chart 1

Flow chart of the CBDC issuance process



Note: The blue boxes cover events that directly affect the central bank's balance sheet while the green boxes refer to events that do not directly affect it.

The creation of CBDC as depicted in Chart 1 can also be captured through a simplified system of financial accounts (see Table 1). CBDC is split into two parts: CBDC1, which substitutes banknotes, and CBDC2, which substitutes sight deposits held with banks. The effects of CBDC1 on the central bank's balance sheet are neutral, but the effects of CBDC2 are not: either banks reduce their (remunerated) "excess" reserves (CBDC2a) – which is only possible if the banking system initially

operates with a liquidity surplus vis-à-vis the central bank (i.e. it holds reserves in excess of its minimum reserve requirements)[11] – or the central bank's balance sheet needs to be lengthened (CBDC2b). To allow for this lengthening, the central bank has to fill the banks' funding gaps by providing them with additional collateralised credit (CBDC2b_credit).[12] Alternatively, the central bank may decide to purchase government and corporate bonds (CBDC2b_bonds) from the banks, so that the total creation of CBDC is the sum of these components:

$$(1) \qquad CBDC = CBDC1 + CBDC2 = CBDC1 + CBDC2a + CBDC2b_{credit} + CBDC2b_{bonds}.$$

Using the shares α, β, γ as defined above allows (1) to be rewritten as

$$(2) \qquad CBDC = (1-\alpha)CBDC + \alpha(1-\beta)CBDC + \alpha\beta(1-\gamma)CBDC + \alpha\beta\gamma CBDC.$$

To note, CBDC will lengthen the central bank's balance sheet if, and only if, $CBDC2b > 0$. This can be shown as follows: CBDC, as a new central bank liability, can only be created via the substitution of existing central bank liabilities, i.e. banknotes (CBDC1) or commercial banks' excess reserves (CBDC2a), or via the lengthening of the central bank's balance sheet through additional central bank credit to banks (CBDC2b_credit) or asset purchases (CBDC2b_bonds).

In principle, it is possible that the introduction of CBDC could change commercial banks' preferences with regard to borrowing from the central bank and their holdings of reserves (in excess of their minimum reserve requirements) beyond their direct needs to credit the household's CBDC account, e.g. as an additional precautionary liquidity demand (see Caccia et al., 2024). The central bank will usually choose, as part of its monetary policy implementation, to reflect such preference changes as quantities on its balance sheet rather than as prices on the interbank market in order to avoid interference with its monetary policy stance. The analysis of the effects on the central bank's balance sheet, profitability and risks put forward in the following sections could easily be extended to include such further changes to the quantities on the balance sheet.

11 We note that the reduction in sight deposits reduces the minimum reserve requirements by the minimum reserve ratio (e.g. 1% in the euro area, 0% for the Federal Reserve System and the Bank of England) and can thus create additional excess reserves (of 1% of CBDC2 in the case of the euro area, zero in the United States and the United Kingdom), which we ignore for purposes of simplicity in this paper. There is a theoretical but highly unrealistic possibility that banks could actively reduce their minimum reserve requirements further to create the excess reserves needed for the exchange for CBDC2 by massively restricting bank lending and thus reducing sight deposits. Central banks will usually adopt policies that avoid such interference from CBDC in their monetary policy stance.

12 For example, the central bank can decide to endogenously accommodate the changing demand for credit operations via standing lending facilities or full allotment operations.

Table 1

Representation of CBDC through financial accounts

Households, pension and investment funds, insurance companies

Assets		Liabilities	
Real assets	X	**All liabilities**	X
Sight deposits with banks	X -CBDC2		
CBDC	0 +CBDC1 +CBDC2		
Banknotes	X -CBDC1		
Bank bonds	X		
Gvt/corp bonds	X		

Commercial banks

Assets		Liabilities	
Loans to gvt/corp	X	**Sight deposits**	X -CBDC2
Gvt/corp bonds	X -CBDC2b_bonds	**Bonds issued**	X
Central bank deposits	X -CBDC2a	**Central bank credit**	X +CBDC2b_credit

Central bank

Assets		Liabilities	
Credit to banks	X +CBDC2b_credit	**Banknotes**	X -CBDC1
Bonds (non-banks)	X +CBDC2b_bonds	**CBDC**	0 +CBDC1 +CBDC2
		Banks' deposits	X -CBDC2a

Notes: The "X" positions stand for stocks prior to any transactions, where X varies across the accounts (i.e. each X in the table is nominally different and could initially be zero).

3 The impact of CBDC on central bank profitability – measured by net interest income

3.1 Methodological approach

Central banks' profits are largely driven by the net interest income on their monetary assets and liabilities. Since CBDC is a new monetary liability for the central bank, our profitability analysis focuses on the impact on net interest income. The implications for operating costs have already been discussed in Section 2.1.

For the profitability impact analysis, we use the stylised central bank balance sheet presented in Table 2 and implied net interest income as a measure of profitability. In a related paper, Gross and Letizia (2023) use an agent-based model to simulate the demand for CBDC and to derive some simulated central bank profits in this context.[13] We present the modelling framework below and results based on different scenarios in the following sections.

Table 2
Stylised central bank balance sheet and related remuneration

Assets			Liabilities		
	Quantity	Remuneration		Quantity	Remuneration
Credit to banks	A_c	r_c	**Banknotes**	L_{bn}	0
Bonds	A_b	r_b	**CBDC**	L_{cbdc}	r_{cbdc}
Net non-monetary policy assets and liabilities	A_{nmp}	r_{nmp}	**Banks' deposits**	L_d	r_d
			Equity	E	0

The remuneration rate always reflects the average accounting return on the operations included in the sub-indexed balance sheet item. Using the Eurosystem as an example:

- r_c is the average return on all lending to banks, comprising main refinancing operations, (targeted) longer-term refinancing operations and the marginal lending facility;
- r_b is the average accounting return on all bonds purchased outright for monetary policy purposes, comprising public sector bonds, covered bonds,

[13] Several macroeconomic models that consider CBDC also include the associated central banks' profits. However, central banks' profits are not the focus of the authors' attention and are usually reflected as lump-sum transfers to the government to close the models (see, for example, Assenmacher et al., 2023; Abad et al., 2023; Bindseil and Senner, 2024b, for a more comprehensive overview).

asset-backed securities and corporate bonds, assuming they are accounted for at amortised cost (i.e. not mark-to-market);[14]

- r_{nmp} is the average return on other non-monetary policy assets and liabilities, which are only included to complete the balance sheet;
- banknotes have no remuneration (almost) by definition;[15]
- r_{cbdc} is the remuneration of CBDC, which the ECB has already announced will be zero;
- r_d is the average return on all banks' deposits ("reserves") held with the Eurosystem, comprising minimum reserve requirements and other holdings of banks in the current account (both currently unremunerated), as well as excess reserves in the deposit facility (remunerated at the deposit facility rate);[16]
- equity has no remuneration.[17]

The usual balance sheet identity of assets and liabilities also applies for central banks:

$$A_c + A_b + A_{nmp} = L_{bn} + L_{cbdc} + L_d + E, \quad (3)$$

which can be rewritten as (Δ indicates a change in the variable):

$$\Delta A_c + \Delta A_b + \Delta A_{nmp} = \Delta L_{bn} + \Delta L_{cbdc} + \Delta L_d + \Delta E. \quad (4)$$

Equation (4) can be rearranged to resemble Chart 1 and equation (1) as described in Section 2.2, i.e. any increase in CBDC has to be balanced by an increase in monetary policy assets (credit to banks and bonds), or a decrease in banknotes or in

[14] Many central banks, such as all central banks in the Eurosystem, as well as the Federal Reserve System, account for their monetary policy securities holdings at amortised cost, while other central banks mark to market their monetary policy portfolios. Marking to market increases the volatility of profits, because in the case of an interest rate increase (such as those seen in recent years) the market prices of bonds immediately decrease and a large unrealised loss would be recorded. Over the entire holding period, total income earned from the holding will be equal under both accounting rules: mark-to-market and amortised cost.

[15] While not applicable for the Eurosystem, a notable exception to this zero remuneration rate is Silvio Gesell's proposal for "depreciative money" in the early 20th century.

[16] Note that the remuneration for bank deposits can be a controversial issue (see, for example, de Grauwe and Ji, 2023) and changes over time according to monetary policy needs. For instance, the Eurosystem applied a two-tier remuneration system for banks' current accounts between October 2019 and September 2022, exempting part of their excess reserves from the negative deposit facility rate. The Eurosystem stopped paying interest on minimum required reserves in September 2023 when ECB key interest rates were at or above 4%. The Federal Reserve System did not pay interest on reserves before October 2008 (see Federal Reserve Board press release for further details).

[17] The impact of profit distribution rules in relation to the impact of CBDC on central banks' capital and net equity is discussed in Section 5.

deposits – and vice versa – while leaving non-monetary policy assets and liabilities, as well as equity, unaffected (i.e. $\Delta A_{nmp} = \Delta E = 0$):[18]

(5) $\Delta L_{cbdc} = \Delta A_c + \Delta A_b - \Delta L_{bn} - \Delta L_d.$

Note the following relationships between equations (1), (2) and (5):

(6) $\Delta L_{cbdc} = CBDC$

(7) $\Delta L_{bn} = -CBDC1 = -(1-\alpha)\Delta L_{cbdc}$

(8) $\Delta L_d = -CBDC2a = -\alpha(1-\beta)\Delta L_{cbdc}$

(9) $\Delta A_c = CBDC2b_{credit} = \alpha\beta(1-\gamma)\Delta L_{cbdc}$

(10) $\Delta A_b = CBDC2b_{bonds} = \alpha\beta\gamma\Delta L_{cbdc}.$

Combining these quantities with their remuneration rates yields the net interest income equation:

(11) $NII = A_c * r_c + A_b * r_b + A_{nmp} * r_{nmp} - L_{cbdc} * r_{cbdc} - L_d * r_d$

and changes in the net interest income equation related to CBDC are as follows:

(12) $\Delta NII = \Delta A_c * r_c + \Delta A_b * r_b - \Delta L_{cbdc} * r_{cbdc} - \Delta L_d * r_d$

Following a "Δ-(changes)-approach" for NII allows us to abstract from the counterfactual size and composition of the central bank's balance sheet in the absence of CBDC at any point in time (reflected in the factors cf_bn and cf_dep in the top blue and green boxes of Chart 1 respectively). This approach allows us to abstract from the profit implications of changes in banknotes in circulation that are independent of CBDC (and discussed in the sensitivity analysis in Section 3.3.2) and of changes triggered by future monetary policy implementation needs.

Assuming CBDC is not remunerated, as in the case of the Eurosystem, we have:

(13) $r_{cbdc} = 0$

(14) $\Delta NII = \Delta A_c * r_c + \Delta A_b * r_b - \Delta L_d * r_d$

(15) $CBDC = (1-\alpha)CBDC + \alpha(1-\beta)CBDC + \alpha\beta(1-\gamma)CBDC + \alpha\beta\gamma CBDC.$

[18] As described in Section 2, access to CBDC is limited to entities that have had no access to the central bank's balance sheet so far other than through holding banknotes. The model focuses on the first-order substitution effects from CBDC issuance. It does not capture potential second-order impacts caused by behavioural changes in the various actors in the financial system. Examples of such behavioural changes include differences in: (i) the amount of government deposits held with the central banks; (ii) the demand for deposits with commercial banks beyond the pure exchange for CBDC; or (iii) the velocity of money, as the time before a given amount of money held for payment is used for this purpose may be different for CBDC, banknotes and commercial bank money.

We can rewrite equation (14) using equations (8), (9) and (10) to obtain:

(16) $$\Delta NII = \Delta L_{cbdc} * \alpha \left(\beta\left((1-\gamma)r_c + \gamma\, r_b\right) + (1-\beta)\, r_d\right) \geq 0 \text{ if } r_c, r_b, r_d \geq 0.$$

This means that the impact on net interest income is equivalent to the size of the CBDC that is not substituted with banknotes by the household multiplied by the weighted average rate of the three balance sheet items that are potentially affected by the introduction of CBDC, namely the central bank's credit to banks and its bond holdings, as well as the deposits of commercial banks.

Equation (16) also shows that the introduction of unremunerated CBDC will have a positive impact on central bank income ($\Delta NII \geq 0$) in a positive interest rate environment ($r_c, r_b, r_d \geq 0$). Note that this positive income impact is the difference compared with counterfactual profits without CBDC at the respective point in time – which will be influenced by structural developments such as the digitalisation of payments and changes in monetary policy – and not the difference compared with the situation today. We discuss the particular case of a negative interest rate environment in Section 3.3.3.

The two corner cases under this set-up are as follows: (i) if the increase in CBDC is fully compensated by a decrease in banknotes $(\alpha = 0)$, there is no impact on profitability given the substitution of two unremunerated liabilities; and (ii) if the increase in CBDC is fully compensated by an increase in bond purchases $(\alpha = 1, \beta = 1, \gamma = 1)$, the impact on profitability will be largest in the likely case that the return on purchased assets is greater than the return on lending to banks.

3.2 Profit projections with CBDC – baseline analyses using euro area data as an example

The model set-up presented above implies that the impact of CBDC on profitability can be represented as a function of seven variables, as formulated in equation (16). Intuitively, the impact depends on the size of the new liability, its effect on the size of other monetary assets and liabilities, and the remuneration of these other monetary assets and liabilities. In this section, we use euro area data to present a baseline analysis and we show different sensitivity analyses in the next section.

We calibrate the three relevant average **remuneration rates** as follows:

- the remuneration of banks' deposits, $r_d = 1.5\%$, reflecting the historical average ECB deposit facility rate from 1999 to 2023;[19]

[19] The historical average value of the ECB deposit facility rate from 1 January 1999 to 31 December 2023, excluding the period of negative interest rates that ran from11 June 2014 to 26 July 2022, which is covered in the sensitivity analysis in Section 3.3.3, equals 155 basis points (as reported in the statistics on key ECB interest rates). Note that future rates will depend on the evolving monetary policy needs, including the level of the neutral real interest rate *r**. Note also that the ECB stopped remunerating minimum reserve requirements in September 2023. In February 2024 minimum reserves made up about 4% of commercial banks' €3.7 trillion of deposits held with the Eurosystem.

- the remuneration of monetary policy credit to banks, $r_c = 2.0\%$, reflecting the 50 basis point spread between the ECB's rate for main refinancing operations and the deposit facility rate between 2019 and 2024;[20]

- the remuneration of monetary policy bond portfolios, $r_b = 2.5\%$, roughly reflecting the average historical term spread between the weighted average maturity of the ECB's net asset purchases and the ECB deposit facility rate.[21]

Based on this calibration, we can rewrite equation (16) as:

(17) $$\Delta NII = \Delta L_{cbdc} * \alpha \left(\beta\left((1-\gamma)2.0\% + \gamma\, 2.5\%\right) + (1-\beta)\, 1.5\%\right)$$

The actual **CBDC take-up** is still somewhat uncertain. As explained in Section 2, the take-up depends on the design of CBDC and the central bank is likely to choose its key design parameters in such a way as to limit demand, thereby reducing the risks of undesired effects on monetary policy and financial stability. Therefore, we consider three different stylised take-up scenarios:[22] (i) a low demand scenario, (ii) a medium demand scenario, and (iii) a high demand scenario.

- For the **low demand scenario**, we assume that demand for CBDC is similar to the average amount of cash held by citizens in their wallets. According to ECB (2022), euro area citizens have an average of €83 in cash in their wallets at the beginning of the day. This can be translated into demand for CBDC of approximately €30 billion.

- For the **medium demand scenario**, we consider that: (i) 50% of euro area residents will adopt the digital euro; (ii) 50% of these will prefund their CBDC wallets (therefore generating a need for CBDC take-up) rather than make full use of the reverse waterfall functionality (which, in an extreme case where users set the limit to zero, would bring CBDC take-up to nil), (iii) over time, they

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20 On 13 March 2024 the ECB announced changes to its operational framework for implementing monetary policy which included a 15 basis point reduction in the spread between the rate on main refinancing operations and the deposit facility rate from 18 September 2024; see footnote 25 for a quantification of the impact. This spread has varied over time depending on monetary policy needs, ranging between 25 basis points from 2013 to 2015 and 100 basis points from 1999 to 2008 (as reported in the statistics on key ECB interest rates). It should be noted that a significant share of the ECB's lending to banks between 2020 and 2022 in the form of targeted longer-term refinancing operations benefited from interest rate discounts of up to 1% below the main refinancing rate under certain conditions.

21 The term spread reflects the average historical spread calculated as the difference between the one-week spot rate and the seven-year spot rate of a composite euro area government curve for the periods of Eurosystem net asset purchases from March 2015 to October 2018 and November 2019 to June 2022. This equals 84 basis points, which we approximate to 1% for simplicity, yielding a remuneration of 2.5% for the bond portfolio. The calibration of seven years is based on the publicly available weighted average maturity of the public sector purchase programme (PSPP) of between 7.1 and 7.4 years (see https://www.ecb.europa.eu/mopo/pdf/PSPP_weighted_average_maturity.xlsx [accessed 1 September 2024]). The PSPP accounts for around 80% of the ECB's asset purchase programme and the remaining share is comprised of private issuers' bonds. European bond markets for private issuers have a shorter average maturity than the average public issuer (no public data on the average maturity of the ECB's private sector purchase programmes are available). The precision of the model could be improved by considering that the term spread is endogenous to the amount of bonds bought by the central bank, but the quantitative relevance is negligible for commonly used elasticities and the amounts of bonds considered in this paper.

22 The stylised scenarios were defined for illustrative purposes in this paper and are without prejudice to the ongoing work of the digital euro project, for example, the Eurosystem workstream on the methodology for the calibration of holding limits. Actual take-up could be higher or lower than these scenarios depending on the final design of the digital euro.

will have digital euro holdings of 50% of the maximum limit allowed on average. We start with a hypothetical maximum CBDC take-up of around €1 trillion based on a hypothetical holding limit of €3,000 per person, in line with e.g. Bindseil, Panetta and Terol (2021), and a potential user base of 349 million euro area residents.[23] Based on these assumptions, we obtain a take-up scenario of around €125 billion (i.e. €1 trillion * 50%^3).

- For the **high demand scenario**, we follow the same reasoning as for the medium demand scenario but select a much higher percentage (80%) in each step. We thus obtain a take-up scenario of approximately €512 billion (i.e. €1 trillion * 80%^3).

Lastly, we turn to the **substitution and asset composition choices of households, banks and the central bank** that are reflected in the flowchart in Chart 1 and in the parameters α, β and γ. We assume for illustrative purposes and simplicity that: (i) households choose to substitute banknotes and sight deposits in equal proportions (i.e. $\alpha = 50\%$); (ii) the central bank enables banks to react to the reduction in households' sight deposits by reducing their deposits with central banks and taking recourse to new liquidity in equal proportions (i.e. $\beta = 50\%$);[24] and (iii) new monetary policy assets are split equally between additional credit to banks and bond purchases (i.e. $\gamma = 50\%$).

Based on the calibration assumption for the medium demand scenario, we obtain an increase in CBDC of €125 billion, which is balanced by a decrease in banknotes of €62.50 billion, a decrease of deposits of €31.25 billion and an increase in assets of €31.25 billion, split evenly between new credit to banks and bond holdings. The outlined balance sheet changes, together with the assumed interest rates, imply a profitability impact in this scenario equal to a €1.17 billion increase in annual net interest income for an average year over the business cycle, as shown in Table 3.[25] The impact in the low demand and high demand scenarios would be €0.28 billion and €4.80 billion respectively. To put these numbers into perspective, the Eurosystem made an average of around €30 billion in annual profits between 2012 and 2021 (see ECB, 2023a). Even the low demand scenario leads to additional seigniorage income of €0.28 billion, i.e. more than double the annual cost of TARGET2 (€0.11 billion).[26]

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[23] See Eurostat data for 2023.

[24] The level of β is likely to either be close to 0% or to 100%, depending on the level of excess reserves in the system relative to the minimum level of excess reserves required to maintain control over interest rates.

[25] If we assume the reduced spread between the rate on main refinancing operations and the deposit facility rate of 15 basis points instead of 50 basis points, in line with the ECB's operational framework since 18 September 2024, this would slightly reduce the net interest income impact in this scenario to €1.12 million, i.e. -€0.05 million (or 5%) less than the impact presented in Table 3.

[26] See "TARGET Annual Report 2022", ECB.

Table 3
Balance sheet and profitability impact in three CBDC demand scenarios

(EUR bn)

	Low demand		Medium demand		High demand	
	ΔBS	ΔNII	ΔBS	ΔNII	ΔBS	ΔNII
Assets						
Credit to banks	3.75	0.08	15.63	0.31	64.00	1.28
Bonds	3.75	0.09	15.63	0.39	64.00	1.60
Liabilities						
Banknotes	-15.00	-	-62.50	-	-256.00	-
CBDC	30.00	-	125.00	-	512.00	-
Deposits	-7.50	0.11	-31.25	0.47	-128.00	1.92
Total	7.50	0.28	31.25	1.17	128.00	4.80

Note: ΔNII reflects the change in annual net interest income for an average year over the business cycle.

It should be noted that the impact of CBDC on net interest income is always calculated relative to the situation with no CBDC at any point in time. Hence, positive impacts on profitability from CBDC may still be over-compensated by other developments that negatively impact central bank profits (see, for example, the alternative scenario of reduced demand for banknotes presented in Section 3.3.2).

3.3 Sensitivity analyses

3.3.1 Substitution rates

The three substitution rates governing the impact of demand for CBDC on the central bank's balance sheet could take different values depending on the preferences of households (α), the reaction of commercial banks and central banks, and existing liquidity conditions (β and γ).

A first sensitivity analysis highlights a linear relationship between the degree of substitution from households' sight deposits into CBDC (α) and the impact of CBDC on the balance sheet size and net interest income. If we take the corner case from Section 3.1, in which the increase in CBDC is fully compensated by a decrease in banknotes ($\alpha = 0$): the balance sheet size and profitability remain the same, given that the substitution involves two unremunerated liabilities. By contrast, if households only exchange sight deposits for CBDC and keep their banknote holdings unchanged ($\alpha = 1$), central bank assets (both credit to banks and bonds), deposits and the corresponding changes in net interest income would double compared with the baseline of $\alpha = 0.5$ in Table 3. In the medium demand scenario, for example, the balance sheet would then increase by €62.5 billion instead of €31.25 billion and net interest income would increase by €2.34 billion instead of €1.17 billion.

According to equation (16), net interest income can be evaluated as the share of CBDC that is not matched with a reduction in banknotes and the weighted average

interest rate of the affected assets and liabilities. As a second sensitivity analysis, Table 4 displays what would happen to the weighted average interest rate if different values for β and γ are used, independently of the household preference parameter α.

Table 4

Net interest rate as a function of the share of newly created reserves (β) and of the share of bond purchases (γ)

$\beta \setminus \gamma$	0%	20%	40%	50%	60%	80%	100%
0%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%
20%	1.60%	1.62%	1.64%	1.65%	1.66%	1.68%	1.70%
40%	1.70%	1.74%	1.78%	1.80%	1.82%	1.86%	1.90%
50%	1.75%	1.80%	1.85%	**1.88%**	1.90%	1.95%	2.00%
60%	1.80%	1.86%	1.92%	1.95%	1.98%	2.04%	2.10%
80%	1.90%	1.98%	2.06%	2.10%	2.14%	2.22%	2.30%
100%	2.00%	2.10%	2.20%	2.25%	2.30%	2.40%	2.50%

Notes: $\alpha = 50\%$. The 50%/50% case presented in the baseline scenario is highlighted in bold.

It is possible to calculate the impact on net interest income by multiplying the selected interest rate by the level of CBDC that is not substituted by banknotes (i.e. $\Delta L_{cbdc} * \alpha$). If we consider the medium demand scenario from the previous section, where $\alpha = \beta = \gamma = 50\%,$ and the resulting net interest rate of 1.88% and ΔNII = €1.17 billion, the impact on profitability ranges from €0.94 billion, when the CBDC that is not matched by a reduction in banknotes is fully substituted by a reduction in banks' deposits (see the top row of Table 4 where $\beta = 0$), to €1.56 billion, when it is fully substituted by an increase in bonds (see the bottom right-hand corner of Table 4 where $\beta = 1, \gamma = 1$). These numbers correspond to a decrease of 20% or an increase of 33% respectively, compared with the medium demand scenario.

3.3.2 Alternative scenario 1: reduction in banknotes

As highlighted in Section 2.1, future demand for banknotes will evolve independently of the endogenous decision of central banks whether to issue CBDC. In particular, the digitalisation of payments might lead the central bank's balance sheet to shrink (see, for example, Kahn et al., 2022). We use two scenarios for a reduction in banknotes to illustrate how these developments could have significant implications for the profitability of central banks.

First, we consider a scenario in which CBDC is not available and where the €125 billion demand for CBDC presented in the medium demand scenario is instead redirected into private forms of payments which, in turn, result in holdings in digital wallets.[27] In this case, if households substituted banknotes to fund half of their

[27] Private forms of payment could theoretically be used, for instance, via existing commercial banks, e-money issuers or crypto-assets.

demand for private forms of payments,[28] we would observe a decrease in the number of banknotes and this would consequently cause the size of the central bank's balance sheet and its profitability to decline. We assume no increase in banks' deposits (i.e. $\beta = 100\%$) because banknotes are treated as autonomous factors in the demand for central bank liquidity (see Section 2.1). Thus, the balance sheet would be shorter by €125 billion with the reduction of assets split as shown in the baseline scenario (i.e. $\gamma = 50\%$), which would have a negative impact on net interest income of €1.41 billion, as displayed in Table 5. This reduction would be larger than the additional profits of €1.17 billion from CBDC in the medium demand scenario.

Second, we consider a scenario in which CBDC is not available and where the demand for banknotes in circulation decreases significantly, by one-third,[29] i.e. a reduction of approximately €500 billion. This could be triggered, for example, if the use of banknotes for payment purposes declines to such an extent that the store of value function and the international role of banknotes are also negatively affected (for instance, because it would become more difficult to gradually spend large stocks of banknotes that had been held for some time as a store of value via consumption). The greater velocity of digital money compared with banknotes could also contribute to such a reduction (see Stella et al., 2021).[30] We assume that such a reduction in banknotes as an autonomous factor will not affect the deposits that commercial banks hold with the central bank and that it would be fully balanced by a reduction in monetary policy assets. In this scenario, net interest income would be reduced by €11.25 billion, i.e. roughly ten times more than the additional profits of €1.17 billion from CBDC in the medium demand scenario.

[28] The other half is assumed to remain as deposits in commercial banks. This assumption captures both cases in which commercial banks are the providers of these new payment services and cases in which households fund their payment accounts outside the traditional banking system (e.g. via e-money providers or crypto-assets) from their commercial bank deposits – which would then be credited to the commercial bank account of the issuer of the e-money or crypto-assets and thus remain as deposits in the banking system.

[29] This reduction of one-third corresponds to *cf_bn* = 2/3 in Chart 1.

[30] A greater velocity of money means a shorter time before a given amount held for payment is used for that purpose.

Table 5

Balance sheet and profitability impact of additional scenarios

(EUR bn)

	Private forms of payments instead of CBDC		Banknotes shock in the absence of CBDC	
	ΔBS	ΔNII	ΔBS	ΔNII
Assets				
Credit to banks	-31.25	-0.63	-250.00	-5.00
Bonds	-31.25	-0.78	-250.00	-6.25
Liabilities				
Banknotes	-62.50	-	-500.00	-
CBDC	0.00	-	0.00	-
Deposits	0.00	0.00	0.00	0.00
Total	-62.50	-1.41	-500.00	-11.25

Note: ΔNII reflects the change in annual net interest income for an average year over the business cycle.

3.3.3 Alternative scenario 2: negative interest rate environment

So far, we have calibrated the three remuneration rates that impact profitability in a positive interest rate environment, $r_c, r_b, r_d \geq 0$. However, the Governing Council of the ECB lowered its deposit facility rate to minus 50 basis points and its main refinancing operations rate to zero for many years. Even if a return to such policies is not expected, it is worth carrying out a sensitivity analysis of the impact of CBDC in a negative interest rate environment.

As a deviation from our baseline analysis, we consider remuneration rates of $r_d = -0.5\%$, $r_l = 0\%$ and $r_b = +0.5\%$,[31] and a monetary policy implementation framework in which r_d is the anchor for short-term interest rates. The negative short-term interest rate may pass through to the interest rate on households' sight deposits with banks. In this context, unremunerated CBDC becomes an attractive alternative to deposits held with banks and thus we use the high demand scenario (€512 billion) for the CBDC take-up rate. In such a negative interest rate environment, it could be expected that households would prefer to substitute more deposits with CBDC than banknotes; therefore we assume $\alpha = 75\%$. In this scenario, the impact on profitability would be negative to the amount of €0.48 billion (see Table 6). This number might be considered fairly small, for example compared with the impact of the Eurosystem's two-tier system for remunerating excess reserve holdings between 2019 and 2022, which exempted between €800 billion and €950 billion of excess reserves from a remuneration rate of -0.5%, implying between €4.0 billion and €4.7 billion in forgone annual interest income on banks' deposits to support "the bank-based transmission of monetary policy, while preserving the positive contribution of

[31] The assumption of constant spreads between r_d, r_l and r_b in this scenario is a simplification. Term premia and thus r_b may be compressed in such a situation. Also, r_l could be lower, in particular if some loans are granted at interest rates below the rate on main refinancing operations, as was the case for some of the ECB's targeted longer-term refinancing operations.

negative rates to the accommodative stance of monetary policy and to the continued sustained convergence of inflation to the ECB's aim."[32]

Table 6

Balance sheet and profitability impact in a negative interest rate environment

(EUR bn)

	High demand for CBDC and negative interest rates	
	ΔBS	ΔNII
Assets		
Credit to banks	96.00	0.00
Bonds	96.00	0.48
Liabilities		
Banknotes	-128.00	-
CBDC	512.00	-
Deposits	-192.00	-0.96
Total	192.00	-0.48

Note: ΔNII reflects the change in annual net interest income for an average year over the business cycle.

[32] See the Eurosystem's Two-tier system for remunerating excess reserve holdings. [Accessed 1 September 2024].

4 Impact of CBDC on central bank financial risk-taking

As CBDC is a new item on central banks' balance sheets, it can also affect their financial risks in multiple ways – although none of these are really new. Banknotes and commercial bank reserves held with a central bank have no market, credit or liquidity risk and thus are generally, and rightly, considered to be risk-free assets in the domestic currency. However, their issuance needs to be matched by central bank assets, which allows for the implementation of monetary policy. These assets are subject to market, credit and liquidity risk, and central banks thus have well-established frameworks in place to manage these financial risks (see, for example, ECB, 2015). This section considers the different channels through which CBDC can affect central banks' financial risk-taking and briefly touches on the non-financial risks.

First, the issuance of CBDC does not directly create additional financial risks: if households only exchange banknotes for unremunerated CBDC (i.e. $\alpha = 0$ and thus CBDC2 = 0), the central bank's balance sheet size, composition of assets and financial risks will remain completely unchanged. Even if households exchange part of their sight deposits held with commercial banks for CBDC (i.e. $\alpha > 0$ and thus CBDC2 > 0), CBDC will not in itself create additional financial risks, only indirect risks through the additional assets that match the additional issuance.

Second, indirect financial risks occur mainly if the issuance of CBDC leads to an increase the central bank's balance sheet or changes the composition of its assets. In previous sections, we have shown that only the creation of additional central bank reserves (i.e. CBDC2b > 0) leads to changes in both the size and composition of the central bank's assets. Therefore, it should implement such changes in a risk-efficient manner, i.e. minimising the financial risk subject to achieving the policy objective (see ECB, 2015). All else being equal, a larger balance sheet size obviously entails larger financial risks. As highlighted in Section 2.1, central banks are likely to take measures, such as ensuring appropriate CBDC remuneration and usage limits, to keep the amount of CBDC in circulation contained.

The composition of the asset side is even more relevant for financial risks than the balance sheet size: additional credit operations can be managed to ensure they have small or even minimal residual credit, market and liquidity risk, particularly if the central bank grants credit only to financially sound counterparties against adequate collateral.[33] By contrast, outright purchases of assets can imply high financial risks,

[33] The Eurosystem has a statutory requirement to conduct credit operations only against adequate collateral. It accepts relatively high-quality assets that are subject to daily valuation (for marketable assets) and haircuts that address the remaining credit, market and liquidity risk of the collateral in the event of a counterparty default. It calibrates the haircuts to cover its expected shortfall at a 99% confidence level (see ECB, 2015).

such as credit risk for corporate bonds.[34] Purchases of longer-maturity bonds either add to interest rate risk (under amortised cost accounting rules, see below) or create market risk (under mark-to-market accounting rules). Nevertheless, asset purchases may be needed for monetary policy reasons, for example, because there may be limits to the extent banks want to borrow from the central bank. Since purchases are subject to the complete discretion of the central bank to govern and execute, their risks can also be efficiently managed using a dedicated framework involving the definition of benchmarks, eligibility criteria, credit risk assessments, due diligence, pricing and limits (see ECB, 2015).

Third, if the financial stability implications of CBDC through its effects on commercial banks' balance sheets are not addressed through careful design decisions, this could ultimately lead to further indirect financial risk effects for the central bank. The potential implications of CBDC for financial stability have been known for some time, and it has been argued that without mitigation measures, CBDC could reduce banks' retail deposit funding and prompt runs on banks, which would imply a need for central banks to be ready to provide additional emergency liquidity assistance (see, for example, CPMI-MC, 2018).[35] Such financial stability risks also exist in a digitalised financial system with no CBDC, as evidenced by the speed and magnitude of uninsured deposit outflows from several US banks in March 2023 (see, for example, Metrick, 2024; Bindseil and Senner, 2024a). Should the conventional banking sector become more fragile, it could lead, inter alia, to a deterioration in the credit risk profile of counterparties to central bank operations.

Central banks such as the ECB have included safeguards in their CBDC designs to address financial stability risks (Bindseil, Cipollone and Schaaf, 2024; Lambert et al., 2024; Meller and Soons, 2023). In addition, central banks can design their credit operations and associated collateral frameworks in such a way that they can effectively and quickly support commercial banks in the event of liquidity shocks, for example, through full allotment policies and/or a standing lending facility/discount window, and by accepting a broad range of assets as collateral. Emergency liquidity assistance has been offered by national central banks in the Eurosystem on several occasions, notably during the great financial crisis and the European sovereign debt crisis but, thanks to prudent risk mitigation measures, this did not lead to credit losses. The reaction of commercial banks to CBDC will also be influenced by regulatory prudential requirements and the monetary policy stance, in addition to economic and financial developments. If, in contrast to their current plans (see Section 2.1), a central bank decides to use remunerated CBDC as a novel instrument to steer monetary policy transmission more directly towards households, and also designs its CBDC so that the effect could be material, then the impacts on the financial system and, in particular, on commercial banks would need to be carefully monitored given their lack of experience with this new transmission

[34] Domestic government bond holdings can also imply financial risks for the central bank: While central banks may consider their domestic sovereigns to be free of credit risk, this is not necessarily the case in a monetary union with multiple sovereigns (see, for example, ECB, 2021, for the related challenges).

[35] If CBDC is wrongly designed, this could create a structural shift away from bank deposits and hamper the funding base, in particular that of commercial banks that rely on retail deposits, as well as increase the frequency and severity of bank runs. In addition to the impact on the funding base, associated liquidity constraints could hamper these institutions' ability to fulfil their regulatory obligations and their credit risk profile could deteriorate as a result.

channel. Such an approach would also have a greater impact on the central bank's balance sheet and its financial risks.

Fourth, the issuance of unremunerated CBDC can change the central bank's interest rate risk. This type of financial risk arises from the different sensitivities of the remuneration of central bank assets and liabilities to changes in interest rates.[36] Since interest rate risk depends on the asset-liability sensitivity mismatch of the whole balance sheet, the "Δ-(changes)-approach" followed in Section 3 for NII needs to be complemented with the interest rate sensitivity of the assets and liabilities that are already on the balance sheet. The income-based repricing gap model (see, for example, Resti and Sironi, 2007) is a useful tool for this task, according to which the gap is defined as the difference between the amount of rate-sensitive assets and rate-sensitive liabilities, with "sensitive" implying that the asset or liability matures or is repriced over a given time period. On the liability side, if households exchange part of their sight deposits for CBDC (i.e. CBDC2>0) and reserves are remunerated, the amount of unremunerated, non-rate sensitive, central bank liabilities increases. In addition, the amount of rate-sensitive liabilities decreases if banks reduce their excess reserves (i.e. CBDC2a>0). On the asset side, central banks' operational frameworks tend to use monetary policy assets to steer short-term interest rates.

Before the great financial crisis, which started in 2007, central banks usually held only short-maturity, and thus interest rate sensitive, assets. Since then, central banks have repeatedly taken duration risk from the market onto their balance sheet via purchases of longer-maturity bonds ("quantitative easing") and have thus increased the share of non-interest rate sensitive assets under amortised cost accounting rules, as applicable for the Eurosystem and the Federal Reserve System, for example. The provision of longer-term lending operations ("credit easing") at fixed interest rates has the same effect.[37] The interest rate sensitivity of the asset side is mainly an implicit consequence of monetary policy needs.[38] At the moment, many central banks have large balance sheets with a negative repricing gap because their rate-sensitive liabilities (L_d) exceed their rate-sensitive assets (limited share of short-maturity A_c and A_b). In this case, CBDC issuance, like banknote issuance, tends to reduce the repricing gap and thus the interest rate risk. By contrast, interest rate risk increases if the central bank balance sheet already has a positive repricing gap, as was common before 2008.[39]

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36 In contrast to the income-based repricing gap model, the equity-based duration gap model focuses on the change in value of assets and liabilities based on their duration. The duration gap model is less relevant for central banks such as the Eurosystem and the Federal Reserve System, the majority of whose long-term assets are accounted for at amortised cost and not marked to market. By contrast, Sveriges Riksbank, for example, uses mark-to-market accounting rules. [Accessed on 1 September 2024].

37 The interest rate on most longer-term Eurosystem credit operations has not been fixed but is linked to the policy rate, so that these operations form part of interest rate sensitive assets also under amortised cost accounting.

38 However, there is some scope for central banks to actively manage other assets such as their foreign reserve portfolio and own funds based on an asset-liability management perspective.

39 If, in contrast to the CBDC design features currently being discussed (see Section 2), CBDC remuneration is not set at zero but linked to the (variable) policy rate, the impact on interest rate risk would obviously be reversed, as part of the unremunerated banknotes (*CBDC1*) would be substituted with remunerated CBDC.

Fifth, from a risk management perspective, it is also important to establish sound risk control measures to protect the central bank's balance sheet in a scenario in which 24/7 access by credit (and payment) institutions could be foreseen. From an implementation standpoint, adaptations may need to be made in payment systems and central bank credit operations to ensure 24/7 availability. From a risk management perspective, this implies the need to actively control, monitor and safeguard the central bank's balance sheet to protect against possible intraday and off-business hours spikes in exposure. It is also important to steer risk management practices to cover this non-stop availability. This would warrant carefully designed risk control measures, where some intraday limits and automatic backstops, for example, could be in place to cap financial risk exposure. Thus, there should be clear governance that includes this scenario, in which monetary policy implementation and risk-related areas work closely together to embrace this wider time availability, leveraging on the current governance for other monetary policy-related issues.

Finally, the adoption of CBDC also changes non-financial risks for central banks, although a detailed assessment of this topic is outside the scope of this paper. The nature of CBDC moves operational risks related to the physical production, distribution and exchange of banknotes (and coins) into the digital sphere.[40] CBDC requires infrastructures and facilities to be built that are heavily reliant on IT systems and potentially prone to cyberattacks. Such operational risks tend to be associated with reputational risks for central banks and require efforts to reduce the likelihood and impact of successful individual events. The Bank for International Settlements has set up "Project Polaris" to support central banks in the design, implementation and operation of secure and resilient CBDC systems to mitigate the operational, legal and reputational risks that central banks face from cyber threats or operational failures.[41]

To summarise, the financial risk implications of CBDC as a new liability for central banks are likely to be mitigated by measures to limit CBDC take-up and can be managed via well-established frameworks. These risks depend on the impact of CBDC on the central bank's balance sheet size and asset composition. All else being equal, the largest increase in financial risks would occur if central banks had to increase the size of their balance sheets via additional outright purchases of long-term assets. If, however, the digitalisation of payments or other factors lead to an overall shrinking of the balance sheet, despite the issuance of CBDC, then seigniorage and financial risks could actually decrease.

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40 See the ECB press release [accessed 1 September 2024] for recent information on counterfeit euro banknotes and the European Banking Authority (2024) for information on payment fraud in relation to existing digital forms of money, focusing on payment instruments for credit transfers, direct debits, card payments, cash withdrawals and e-money transactions.

41 See BIS Innovation Hub, "Project Polaris: secure and resilient CBDC systems, offline and online", 26 October 2023 [accessed 1 September 2024] and, in particular, BIS (2023).

5 Impact of CBDC on central bank capital and net equity

Since the introduction of CBDC can affect both the central bank's profits (Section 3) and financial risks (Section 4), it can also impact the actual and desired amount of capital and its (more broadly defined) net equity. This section first explains the general link between net interest income and the central bank's capital/net equity. It then turns to the impact of CBDC on capital/net equity, building on the key drivers of the impact identified in previous sections.

Given the diversity of their accounting rules, and also the different arrangements with their shareholders, central banks do not have harmonised definitions of financial strength, net equity or financial buffers. These definitions usually start with the central bank's capital, then add accounting reserves (not to be confused with the deposits held by commercial banks with the central bank, which we called "reserves" above!), general risk provisions and revaluation accounts. They may also subtract losses carried forward from previous years when relevant and consider the profit/loss for the year. Moving from this accounting-oriented perspective to more economic measures, the financial strength of a central bank can also be calculated by valuing all balance sheet items at their market price. The most comprehensive view of the financial strength of a central bank takes into account the present discounted value of future seigniorage income (see, for example, Buiter, 2020), and the stock of banknotes can also be seen as part of its comprehensive net worth (see Archer and Moser-Boehm, 2013).

In principle, a central bank's net interest income combined with its net other operating income yields its annual net income. This annual net income is either used to increase the central bank's financial buffers or distributed as a dividend to its shareholders (usually the government; sometimes (also) the private sector). The policy implications of considerations surrounding a central bank's financial strength make it useful to distinguish between the stand-alone balance sheet of the central bank and the consolidated balance sheet of the public sector (see, for example, ECB, 2021). For example, Bunea et al. (2016) analyse how the financial strength of a central bank is affected by its profit distribution and accounting rules. According to Bunea et al. (2016), profit distribution rules can have a material impact on the financial strength of a central bank, particularly when profits are volatile, and furthermore "[a]n inappropriate profit distribution policy can interfere with the objectives of monetary policy" (op. cit., p. 34). In this context, the greater net worth deriving from higher average seigniorage could suggest less need for accounting buffers on the balance sheet. At the same time, greater profit volatility (either because of the nature of the underlying operations, the balance sheet structure or because of the accounting rules) could suggest a greater need for financial buffers to smooth out profit distribution and avoid situations of negative net equity – even if they do not prevent the central bank from operating.

The analysis in the preceding sections shows that the impact of unremunerated CBDC on a central bank depends crucially on which of the following three ways CBDC is created.

First, the exchange of banknotes for CBDC (CBDC1) is a simple shift between two unremunerated central bank liabilities with no further implications for the central bank's net interest income, profits (abstracting from operational costs) or financial risks. It should thus have no implications for its capital and net equity.

Second, the exchange of households' sight deposits held with banks for CBDC via a reduction in commercial banks' excess reserves (CBDC2a) represents the exchange of a remunerated central bank liability (banks' reserves) for an unremunerated central bank liability (CBDC) with no impact on the overall balance sheet size. However, it increases average seigniorage/net interest income in a normal (positive) interest rate environment. Based on the balance sheets of many central banks today, with a large share of non-interest rate sensitive assets and thus a negative repricing gap, CBDC2a would reduce the central bank's interest rate risk, i.e. make net interest income less volatile to changes in interest rates. If the asset side is sufficiently interest rate sensitive to have a positive repricing gap, however, the higher average profits will also be more volatile. In any case, the central bank can decide whether to use the additional income generated as a result of the introduction of CBDC to increase its capital/net equity by increasing its general risk provisions[42] or accounting reserves. It can alternatively distribute the profits to the government, in line with the respective local preferences, needs and profit distribution rules (see, for example, Bunea et al., 2016).

Third, the exchange of households' bank deposits for CBDC results in additional central bank credit for banks/purchases of bonds (CBDC2b) and thus lengthens the central bank's balance sheet. The income from the additional credit/bonds on the asset side, which are "financed" by unremunerated CBDC, increases the average seigniorage/net interest income. The impact on interest rate risk and net interest income volatility is the same as for CBDC2a if all additional credit/bonds are fully interest rate sensitive. The lower the interest rate sensitivity of the additional credit/bonds, the less the CBDC2b issuance changes income volatility compared with the initial stage, i.e. before the introduction of CBDC. The composition of the additional assets for CBDC2b can lead to more financial risks, in particular credit risk in the case of bond purchases. This is also reflected in the higher expected income compared with CBDC2a and may lead to a need for greater general risk provisions and reserves on the central bank's balance sheet. Furthermore, the selection of the accounting rules (amortised cost or mark-to-market) for the additional assets can

[42] The ECB reviews the level of its general risk provision on a basis of the central bank's overall risk exposure (see Article 8 of Accounting Guideline ECB/2016/34).

impact the volatility of the central bank's profits and thus its need for capital/net equity.[43]

Another potentially even more important result of our analysis relates to the quantitative relevance of CBDC versus other factors that are likely to influence the central bank's capital in the future. Most central banks, including the ECB, are considering introducing CBDC with safeguards that would significantly constrain the amount of CBDC in circulation. If CBDC is implemented with such safeguards, its impact on profits and thus on the central bank's capital would be less relevant than the impact of the future demand for banknotes and digital payment solutions in the absence of CBDC. The same applies to the implications for balance sheet size and the composition of future monetary policy implementation frameworks.

[43] Schwarz et al. (2014) show that Eurosystem accounting rules (hold-to-maturity assets at amortised cost subject to impairment) were more beneficial in preserving the financial buffers and thus the financial strength of the ECB from 1999 to 2013 than the counterfactual simulation of IFRS rules (mark-to-market). These results are driven by the lack of protection from the distribution of unrealised profits to shareholders under IFRS because of the symmetrical recognition of unrealised results in IFRS-based income statements, which does not exist under the Eurosystem accounting rules.

6 Conclusion

This paper has focused on the impact of CBDC, a new liability for central banks, on their balance sheets, profitability, risk-taking and capital. The choices made by households, commercial banks and central banks shape the impact of CBDC issuance on the central banks' balance sheets. Central banks have announced that if they issue CBDC, they will do so with holding limits and with no remuneration. The ECB, for example, has also announced access constraints (for example, granting access only to domestic natural persons) and sweep facilities that allow users to avoid the excessive use of digital euro as a store of value. All these design features limit the likely demand for CBDC as a store of value and therefore reduce the impacts on central banks' balance sheets (and on the balance sheets of commercial banks). Furthermore, the demand for banknotes in circulation might increase at a slower pace than in the past, or even decrease, owing to the digitalisation of retail payments. The limited distinguishability of banknotes and unremunerated CBDC from a balance sheet and profit perspective would suggest that the outlook for the balance sheets, profitability and capital needs of central banks over the coming decades is neither very different from – nor more uncertain than – the way it has been in the past. Moreover, the contribution of CBDC is more likely to stabilise the outlook as it aims to preserve the use of central bank money.

This perspective differs from the usual narrative that the issuance of CBDC will necessarily imply a much larger central bank balance sheet, and therefore considerably more elevated financial risks and higher capital needs. This narrative was legitimate while CBDC design features were unknown and there was a possibility that CBDC could be issued without limits and remunerated. However, such assumptions are now outdated, at least for the digital euro, with design features that clearly disincentivise (and limit) the store of value function. Nevertheless, in the quantitative parts of the paper we also consider the possibility that CBDC could significantly increase central banks' balance sheets, as this may be true for other CBDC designs.

We develop a model to quantify the change in central banks' net interest income compared with a balance sheet without CBDC. This is then applied for the euro area and the potential introduction of a digital euro under different scenarios. While a pure exchange of banknotes for CBDC has no further implications on central banks' balance sheets, the exchange of households' sight deposits held with banks for CBDC increases the amount of unremunerated monetary liabilities for central banks and may require the creation of additional reserves for banks via the corresponding additional central bank assets. The last two points would tend to give rise to higher income for central banks in a positive interest rate environment. This additional income would be relatively modest given the design features of the digital euro because of the expected low take-up and could, in principle, be distributed as dividends to the government (and possibly other shareholders). However, as these additional assets could lead to an increase in financial risks, central banks may

prefer to use part of the additional income to shore up their financial buffers, thus supporting their capital and financial independence and reinforcing their credibility.

The financial risk implications of CBDC for central banks arise primarily through the amount and composition of the additional assets that match the additional issuance of central bank liabilities. The risk implications can be managed via well-established frameworks and likely be mitigated by measures to limit CBDC take-up. All else being equal, a central bank's financial risks would increase most significantly if it had to increase the size of its balance sheet via additional outright purchases of long-term assets. However, the effect on its interest rate risk is ambiguous: interest rate risk decreases if the central bank's balance sheet with no CBDC has a negative repricing gap between interest rate sensitive assets and liabilities (as is common nowadays) and vice versa for a positive repricing gap (as was common before 2008).

There is in any case considerable uncertainty surrounding the future size and composition of central banks' balance sheets. Monetary policy needs will evolve and the still sizeable balance sheets seen today, following the pandemic-related quantitative easing measures, may shrink further. Moreover, central banks' decisions to issue CBDC are endogenous to the general shift in societal habits towards digital means of payment. From this perspective, the introduction of CBDC may be seen as a stabilising factor not only for the role of central bank money within the overall monetary architecture, but also for the profitability of central banks.

7 References

Abad, J., Nuño Barrau, G. and Thomas, C. (2023), "CBDC and the operational framework of monetary policy", *BIS Working Papers*, No 1126, Bank for International Settlements.

Adalid, R., Álvarez-Blázquez, A., Assenmacher, K., Burlon, L., Dimou, M., López-Quiles, C., Martín Fuentes, N., Meller, B., Muñoz, M.A., Radulova, P., Rodriguez d'Acri, C., Shakir, T., Šílová, G., Soons, O. and Ventula Veghazy, A. (2022), "Central bank digital currency and bank intermediation", *Occasional Paper Series*, No 293, ECB.

Archer, D. and Moser-Boehm, P. (2013), "Central bank finances", *BIS Papers*, No 71, Bank for International Settlements.

Ahnert, T., Assenmacher, K., Hoffmann, P., Leonello, A., Monnet, C. and Porcellacchia, D. (2024), "The economics of central bank digital currency", *International Journal of Central Banking*, Vol. 20, No 4, pp. 221-274.

Bell, S., Chui, M., Gomes, T., Moser-Boehm, P. and Pierres Tejada, A. (2023), "Why are central banks reporting losses? Does it matter?", *BIS Bulletin*, No 68, Bank for International Settlements.

Bindseil, U. (2020), "Tiered CBDC and the financial system", *Working Paper Series*, No 2351, ECB.

Bindseil, U., Cipollone, P. and Schaaf, J. (2024), "The digital euro after the investigation phase: Demystifying fears about bank disintermediation", *VoxEU*, 19 February.

Bindseil, U., Manzanares, A. and Weller, B. (2004), "The role of central bank capital revisited", *Working Paper Series*, No 392, ECB.

Bindseil, U., Panetta, F. and Terol, I. (2021), "Central Bank Digital Currency: functional scope, pricing and controls", *Occasional Paper Series*, No 286, ECB, December.

Bindseil, U. and Lanari, E. (2022), "Fire Sales, the LOLR, and Bank Runs with Continuous Asset Liquidity", *Journal of Financial Crises*, Vol. 4, No 4, pp. 77-102.

Bindseil, U. and Senner, R. (2024a), "Destabilisation of bank deposits across destinations: assessment and policy implications", *Working Paper Series*, No 2887, ECB.

Bindseil, U. and Senner, R. (2024b), "Macroeconomic modelling of CBDC: a critical review", *Working Paper Series*, No 2978, ECB.

BIS Innovation Hub (2023), "Project Polaris – Part 2: A security and resilience framework for CBDC systems", Bank for International Settlements, July.

Broeders, D., Houben, A. and Bonetti, M. (2024), “Central Bank Capital in Turbulent Times – The Risk Management Dimension of Novel Monetary Policy Instruments”, Springer Nature Switzerland, forthcoming.

Buiter, W. (2020), “Central banks as fiscal players: The Drivers of Fiscal and Monetary Policy Space”, *Federico Caffè Lectures*, Cambridge University Press, Cambridge, United Kingdom.

Bunea, D., Karakitsos, P., Merriman, N. and Studener, W. (2016), “Profit distribution and loss coverage rules for central banks”, *Occasional Paper Series*, No 169, ECB, April.

Caccia, E., Tapking, J. and Vlassopoulos, T. (2024), “Central bank digital currency and monetary policy implementation”, *Occasional Paper Series*, No 345, ECB.

CPMI-MC (2018), “Central bank digital currencies”, *Joint report of the Committee on Payments and Market Infrastructure and the Markets Committee*, Basel, March.

De Grauwe, P. and Ji, Y. (2023), “Fighting Inflation More Effectively without Transferring Central Banks’ Profits to Banks”, *CESifo Working Paper*, No 10741, November.

Devigne, L., Michel, V., De Pastor, R. and Tricot, J. (2023), “Despite inflation, Europeans are still holding on to their banknote reserves”, *Eco Notepad*, Banque de France, 18 December.

European Banking Authority (2024), “2024 report on payment fraud”.

European Central Bank (2015), “The financial risk management of the Eurosystem’s monetary policy operations”, July.

European Central Bank (2021), “Central bank solvency and mechanisms for safeguarding central bank independence: a brief literature review”, Box 2 in “Monetary-fiscal policy interactions in the euro area”, *Occasional Paper Series*, No 273, September.

European Central Bank (2022), “Study on the payment attitudes of consumers in the euro area (SPACE) – 2022”, December.

European Central Bank (2023a), “Profits and losses of the ECB and the euro area national central banks: where do they come from?”, *ECB Explainers*, updated on 19 May, accessed on 1 September 2024.

European Central Bank (2023b), “A stocktake on the digital euro – Summary report on the investigation phase and outlook on the next phase”, 18 October.

Goncharov, I., Ioannidou, V. and Schmalz, M.C. (2023), “(Why) do central banks care about their profits?”, *The Journal of Finance*, Vol. 78, No 5, pp. 2991-3045.

Gross, M. and Letizia, E. (2023), "To Demand or Not to Demand: On Quantifying the Future Appetite for CBDC", *IMF Working Paper*, No 2023/009, International Monetary Fund, Washington D.C.

Kahn, C., Singh, M. and Alwazir, J. (2022), "Digital Money and Central Bank Operations", *IMF Working Paper*, No 2022/085, International Monetary Fund, Washington D.C.

Lambert, C., Meller, B., Pancaro, C., Pellicani, A., Radulova, P., Soons, O. and van der Kraaij, A. (2024), "Digital euro safeguards – protecting financial stability and liquidity in the banking sector", *Occasional Paper Series*, No 346, ECB.

Meller, B. and Soons, O. (2023), "Know your (holding) limits: CBDC, financial stability and central bank reliance", *Occasional Paper Series*, No 326, ECB.

Metrick, A. (2024), "The Failure of Silicon Valley Bank and the Panic of 2023", *Journal of Economic Perspectives*, Vol. 38, No 1, pp. 133-152.

Resti, A. and Sironi, A. (2007), "Risk management and shareholders' value in banking", Wiley, Chichester, United Kingdom.

Schwarz, C., Karakitsos, P., Merriman, N. and Studener, W. (2014), "Why accounting matters: a central bank perspective", *Occasional Paper Series*, No 153, ECB.

Simmel, G. (1900), "Philosophie des Geldes", Duncker & Humblot, Leipzig, Germany.

Stella, P. (1997), "Do Central Banks Need Capital?", *IMF Working Paper*, No 1997/083, International Monetary Fund, Washington D.C.

Stella, P., Singh, M. and Bhargava, A. (2021), "Some Alternative Monetary Facts", *IMF Working Paper*, No 2021/006, International Monetary Fund, Washington D.C.

Wessels, P. and Broeders D. (2022), "On the capitalisation of central banks", *Occasional Studies*, Vol. 20, No 4, De Nederlandsche Bank.

Zamora-Pérez, A. (2021), "The paradox of banknotes: understanding the demand for cash beyond transactional use", *Economic Bulletin*, Issue 2, ECB.

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