BANCA D'ITALIA
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Questioni di Economia e Finanza

(Occasional Papers)

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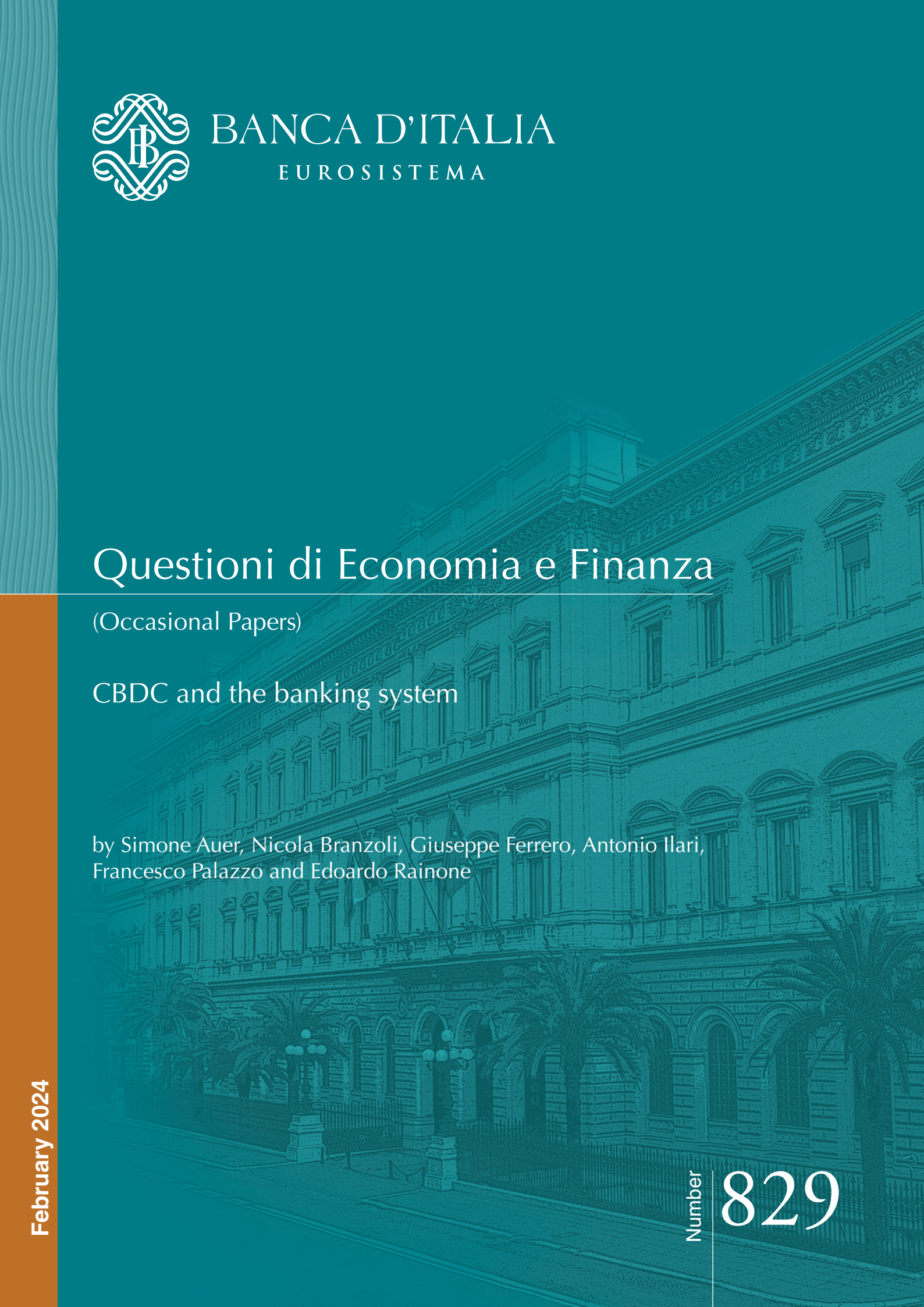

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CBDC AND THE BANKING SYSTEM

by Simone Auer[*], Nicola Branzoli[**], Giuseppe Ferrero[*],
Antonio Ilari[***], Francesco Palazzo[**] and Edoardo Rainone[**]

Abstract

This paper describes the role of central bank and commercial bank money in a modern monetary system and the possible implications of the introduction of a central bank digital currency (CBDC) for the banking system and the economy as a whole. The analysis shows that the impact of a CBDC depends on a number of design choices and on how credit institutions re-optimize their balance sheets in response to the outflow of deposits caused by the substitution of private money with public digital money. We provide a set of illustrative simulations on the impact of a CBDC on the funding structure and profitability of credit institutions using data on Italian banks between June 2021 and March 2023. The analysis suggests that the overall impact on banks' funding could be manageable in the presence of individual holding limits and in an environment characterized by ample liquidity and stable funding for credit institutions. The cost of covering the reduction of deposits would be relatively higher for intermediaries with low excess reserves and for those that may need to issue long-term liabilities to maintain stable funding levels above regulatory requirements.

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Executive summary

The increasing digitalization of the economy, the potential proliferation of assets issued on distributed ledger technologies (DLTs) and the gradual reduction in the use of banknotes are fuelling the debate about whether central banks should issue a retail central bank digital currency (CBDC) and which characteristics it should have.

A CBDC available to the public would complement central bank reserves and banknotes (the two existing forms of public money) – with a wider access than the former, currently held almost exclusively by banks, and a digital form unlike the latter – and provide a digital monetary anchor for private money. A CBDC would help ensure the integrity of digital payments, promote financial inclusion, and act as a catalyst for innovation in finance and commerce more broadly. Alongside these benefits, a retail CBDC faces significant challenges. For example, if inappropriately designed, a CBDC may raise privacy concerns by allowing central banks to collect unprecedented amounts of sensitive data on users' behaviours and it may raise monetary policy and financial stability issues by reducing the amount of bank deposits in the economy.

In light of these potential benefits and challenges, this paper describes the role of central bank and commercial bank money in a modern monetary system and the potential implications of the introduction of a CBDC for the banking system and the macroeconomy. First, we consider the role of CBDC characteristics in determining its adoption and the possible channels through which a CBDC could directly affect banks' balance sheets and set in motion a series of indirect effects on the economic system more broadly. Second, at a conceptual level, we analyse the implications for financial intermediaries' profitability, capitalization, liquidity and stability. Third, we review the theoretical literature on these effects, which are generally difficult to assess in practice given the lack of available evidence. This analysis shows that, for a given set of CBDC characteristics, the implications for the banking system and the macroeconomy depend on the degree of competition in the deposit market and on how credit institutions would re-optimize their balance sheet in response to possible deposit outflows. In particular, under perfect competition, the introduction of a CBDC may lead to a decrease in deposits and a contraction in bank lending. If, on the other hand, banks have market power, the introduction of a CBDC may increase competition and, as a consequence, also deposits and lending may increase.

To shed light on how credit institutions may re-optimize their balance sheet, in the second part of this work we run a series of illustrative simulations to assess the potential impact of a CBDC on the funding structure and profitability of banks, using supervisory and market data from June 2021 to March 2023 on Italian banks. The analysis is carried out under two extreme assumptions. First, it is assumed that banks have no market power and therefore that the supply of deposits is perfectly inelastic; as a consequence, a CBDC would not affect banks' pricing decisions and would lead to a mechanical outflow of deposits. Second, the counterfactual scenario of the simulations is the status quo of an economy without the CBDC; it does not take into account potential developments in the payments market of new forms of digital private assets, such as global stablecoins, and their impact on the banking system in the absence of a CBDC. These assumptions are unlikely to be true in practice, however they are useful benchmarks to isolate and understand the main channels through which a CBDC may affect credit institutions.

The analysis suggests that the impact of a CBDC on the funding structure of banks would be manageable if its demand were below 15 per cent of retail deposits; it could become relevant with a larger adoption in the absence of individual holding limits, especially if there were a relatively low amount of liquidity in the banking system. Ample liquidity and stable funds would allow intermediaries to cover most of deposit outflows with reserves and secured short-term funding. The impact on the profitability of individual banks would be broadly similar if the deposit outflow were relatively small, while it would be more dispersed across credit institutions if the demand for CBDC were relatively large. Banks with low excess reserves and those that may need to issue long-term liabilities to maintain stable funding levels above regulatory requirements would face relatively higher costs from covering the reduction of deposits.

Overall, the illustrative exercises suggest that potential adverse impact of a CBDC on the banking system could be avoided by design choices that limit the substitution of retail deposits in an environment of ample liquidity and available buffers of stable funding across banks. These observations might be particularly relevant during the initial period of the introduction of a CBDC, when there will be considerable uncertainty about its demand.

1. Introduction

The evolution of money over time is a story of interconnectedness between technological progress and institutional adaptation. Central bank digital currency (CBDC) – a type of money based on digital technology and issued by the institution in charge of managing public money – is a further step along this path.

By simultaneously fulfilling the functions of unit of account, store of value and means of payment, money has enabled a more efficient production and allocation of goods and services across space and time in increasingly complex economic systems.

The effectiveness of money in performing these three functions ultimately depends on technology and institutions. The fundamental problem with any payment technology – the set of technical tools and procedures by which money is created, stored and transferred, making it possible to extinguish the obligations arising from the exchange activity – is the uncertainty that surrounds the monetary contract: to what extent can the payees be sure that what they receive is really money? Will they always be able to find someone else who will accept their money without loss of (nominal) value at any time? How can payers be sure that what they give effectively releases them from any obligation to the payees at the moment they accept it?

Because of this uncertainty, the effectiveness of a given payment technology is conditioned by the existence of institutions and rules that support the trust of its users (Giannini, 2011). The set of technologies and institutions involved in this process constitute the payment system within which money circulates.

In modern monetary economies, households and firms use different forms of money interchangeably as long as they are denominated in the same currency. The existence of a form of money issued by a public institution (the central bank), into which other means of payment issued by private institutions (mainly commercial banks) can be exchanged at par value, provides a common "monetary anchor" for all private forms of money and gives rise to the "singleness of money"[1]: the certainty that "one euro is one euro", whatever form it takes (whether the issuer is the central bank or a commercial bank, whether tangible or intangible). This "singleness" is a necessary (but not in itself sufficient) condition for a currency to effectively become the unit of account shared by agents in the economy, with the associated benefits of efficiency and safety in trade.

[1] See Garratt and Shin (2023).

In a fiat monetary system, where money is not backed by a physical asset such as gold, its effective use depends on the general acceptance of pieces of paper (or bits in a digital ledger) that cannot be redeemed in anything other than themselves. General acceptance is what ultimately makes them valuable, along with trust that payments made with them can irrevocably extinguish obligations (i.e., they have legal tender status), and that the institutions charged with managing and regulating them are effectively able to preserve the value of the money stock as a whole, i.e. not just the small fraction they directly issue (De Bonis and Ferrero, 2021).

In recent years, the proliferation of new technologies that allow information to be created, transferred, and stored in a decentralized and diffuse manner (i.e. distributed ledger technologies, DLTs), the emergence of new types of financial assets based on such technologies (i.e. crypto-assets, including stablecoins) and the progressive reduction in the use of banknotes and coins for payments have led to a debate about whether the central bank should issue a new form of digital currency, the CBDC, and what characteristics it should have.

The possibility that this new currency could become a substitute not only for the type of money already issued by central banks, but also for other forms of money currently issued within the private sector, is an issue that is currently being analysed (also) to understand the possible broader implications for the financial system, the monetary policy and the real economy. This is the subject of the remainder of this paper.

Section 2 provides a qualitative description of the potential impact of the introduction of a CBDC on the banking system; Section 3 provides a quantitative assessment using Italian data; Section 4 concludes.

2. CBDC: a new form of public money

In modern monetary economies, central banks are the institutions responsible for maintaining trust in money and the safety and integrity of the payment system.

Central banks are not the only money issuers in the economy. Commercial banks are the other main issuers, and their liabilities actually account for most of the stock of retail money. The multiplicity of money issuers and payment service providers is seen as an essential element of an efficient economy.

In this system, participants hold funds ("deposits") with a common agent ("settlement institution").[2] Payments between participants are made by exchanging the liabilities of the settlement institution (the "settlement asset"). Deposits with the settlement institution are accepted as means of payment by all participants.

The payment system plays a fundamental role in the economy by providing a set of mechanisms through which wholesale and retail transactions can be easily settled. The former typically settles large-value transactions between financial institutions. The latter handles a large volume of relatively low-value payments, in such forms as credit transfers, direct debits, cheques, card payments and electronic-money (e-money) transactions.

Central banks provide the ultimate safe asset (i.e. central bank money) to settle both wholesale (with reserves) and retail (with banknotes) transactions and to support their core objectives of maintaining macroeconomic, monetary and financial stability and promoting the efficiency of the payment system.

Banks compete for end users, while the central bank ensures the interoperability of commercial bank money and provides the institutional mechanisms to maintain confidence in the payment system as a whole. Ultimately, commercial bank money derives its value from the legal promise of convertibility into central bank money at par and on demand.[3]

To underpin this promise, the central bank also acts as the ultimate source of liquidity for commercial banks (lender of last resort). Prudential regulation and supervision – often carried out by the central bank – limit the moral hazard of banks that might arise from the implicit insurance provided by a lender of last resort and their risk of failure, while deposit insurance schemes can help prevent runs and ensure that depositors are repaid up to a certain threshold in the event of default.[4]

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[2] CPSS (2003). CPSS stood for Committee on Payment and Settlement Systems and became the Committee on Payments and Market Infrastructures (CPMI) in 2014.

[3] Conversion at par removes the very high transaction costs that could arise for users of a currency if there were multiple issuers whose monies were exchanged at different values. Conversion between commercial and central bank monies takes place in a tangible manner when a commercial bank depositor withdraws banknotes from an account. Conversion between different commercial bank monies takes place through payment systems when a customer of one bank makes a payment to a customer of another bank, using central bank money as the bridge in most cases.

[4] Since the objective of this paper is to analyze in detail the effects of a CBDC on the other forms of money used in market economies and on their issuers (the banking system and the central bank), Appendix 1 provides a detailed description of the functioning of a modern monetary system.

2.1. The role of commercial banks in modern monetary systems

In modern monetary economies commercial banks do not only play an important role in the payment system by transferring and storing money, but also carry out a wide range of activities that are essential for the well-functioning of any economy. In particular, banks simultaneously grant loans *and* issue deposits, thereby providing the important service of maturity and liquidity transformation, which improves the allocation of households' consumption and firms' capital across time and agents.

The academic literature has identified the presence of market frictions, information asymmetries and limited commitment as the reasons why the coexistence of deposits and loans within the balance sheet of a single institution may increase allocative efficiency. Donaldson et al. (2018) highlight that banks emerge thanks to a superior storage technology and their legal right to seize a defaulting borrower's deposits. Gu et al. (2013) argue that bankers are agents with characteristics − discount factor, ability to monitor, low convenience from diverting resources, high stake in the economy − that make them less inclined to default; this in turn allows banks to simultaneously originate loans and deposits, with the latter circulating as money. Diamond and Rajan (2001) instead provide a rationale for the pervasive role of maturity transformation in banking based on liquidity and limited commitment problems for borrowers and lenders. An important implication of their model is that the inherent vulnerability of banks to "runs", originally identified in a formal model by Diamond and Dybvig (1983), is a/the fundamental reason for exerting market discipline on lenders, which in turn translates into more favourable loan terms for borrowers.

Through their role in transforming maturity and liquidity, banks also play a crucial role in the transmission of monetary policy decisions to the consumption, saving and investment decisions of households and firms.

Despite the early contribution of Fischer (1933) on the negative real effects of debt deflation, the *money view* (Friedman and Schwartz, 1963) and the subsequent *real business cycle theory* (Kydland and Prescott, 1982) underplayed for a long time the autonomous role of financial markets and financial intermediation in determining real economic outcomes. In a sense, they implicitly supported the realworld validity of the assumptions underlying the Modigliani and Miller (1958) theorem on the irrelevance of the capital structure of firms and banks. However, it gradually became clear that this view could not account for several empirical puzzles. This led to the development of an alternative *credit view* (Bernanke, 1983;

Bernanke and Blinder, 1988; Bernanke, 1989), which emphasizes the importance of the banking sector's ability to provide funds to the economy and its role in the transmission of monetary policy.

Monetary policy decisions affect the demand and the supply of credit and deposits through several channels.

First of all, a change in short-term interest rates - induced by a change in policy rates - or in the medium and long-term interest rates - induced by asset purchase programs or forward guidance - affects the interest rates paid by banks on deposits and those charged on loans (the *interest rate channel*). As a result, savings, consumption and investment decisions are also affected.

In addition, financial frictions introduce heterogeneous effects on economic agents and lead to amplification mechanisms that increase the impact of monetary policy relative to an Arrow-Debreu setting with complete markets. In particular, two main sub-channels of monetary policy transmission could be identified.

First, the so-called *balance sheet channel* focuses on the role of collateral constraints (Bernanke and Gertler, 1989; Bernanke and Gertler, 1995; Kiyotaki and Moore, 1997). Changes in current and expected interest rates can affect borrowers' net wealth (current and future) and thus their ability to borrow. For example, a fall in interest rates may reduce the cost of debt and increase the value of collateral used to borrow (thereby easing borrowing constraints).

Second, the *bank lending* channel points to the imperfect substitutability of different liabilities for both firms (James, 1987; Kashyap et al., 1993; Kashyap and Stein, 1995; Holmstrom and Tirole, 1997) and banks (Bernanke and Blinder, 1992; Peek and Rosengren, 1994; Stein, 1998; Kashyap and Stein, 2000; Van den Heuvel, 2002), which affects the overall financial capacity of the economy. The main implication of the bank lending channel is that a restrictive monetary policy would disproportionately affect banks with less liquid assets, as they would have less scope to adjust deposit outflows by reducing banknotes and liquid securities, and less capital, as it would be costlier for them to access uninsured sources of funding.

Finally, monetary policy measures that affect the slope of the yield curve modify banks' interest rate margins and profitability, and their attitude to credit risk when granting new loans (the *risk-taking channel).*[5]

[5] Theoretically, the link between profitability and risk taking is unclear. "Reach-for-yield" models suggest that when the yield curve flattens, intermediaries seeing their interest margins, equity value and risk-bearing capacity lowering would refrain from risk-taking activities and reduce credit

As maturity and liquidity transformation is risky and lies at the root of banks' inherent fragility, academics and policy makers have long debated its merits and the most appropriate policy instruments to mitigate its potential adverse effects for financial and price stability (e.g. deposit insurance, capital and liquidity requirements, monetary policy).

If the banking system expands its balance sheet excessively by granting "too many" loans, the risk that some of these loans will not be repaid increases; if many borrowers are unable to repay their debts at the same time, the value of the assets on the bank's balance sheet is reduced and the likelihood of the bank incurring losses increases, which would lead to a reduction in the bank's capital; the risk of the bank becoming insolvent increases and, in a monetary system in which banks are highly interconnected with each other and with other financial intermediaries, the risks to financial stability increase.

Moreover, if a fractional banking system creates and lends "too much" money, the gap between the money it has created (deposits) and the most liquid part of its assets (central bank reserves and government securities) widens; if a large number of depositors simultaneously ask the bank to withdraw (or transfer) their deposits, the bank will find it difficult to raise reserves by selling its illiquid financial assets, or will be able to do so, but only at a price below their fair value (illiquidity risk); insolvency risks could arise for the bank itself and for the system as a whole. However, there are limits to the creation of deposits in a fractional system.

The first limitation comes from the demand for funds. Since deposits are mainly created by granting new loans, the amount of new deposits created at any given time depends (to a large extent) on the demand for loans by households and firms. This, in turn, also depends on the interest rate charged by banks, which is linked to monetary policy interest rate decisions and thus to macroeconomic conditions, as well as to the borrower's ability to generate future income and to meet its obligations. In other words, interest rates and current and future economic conditions act as the main brake (or stimulus) on deposit growth.

A second constraint comes from regulation and prudential supervision. Both those who demand deposits (i.e., households and firms) and those who supply

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supply (see Adrian and Shin, 2010a, 2010b). On the other hand, when the interest margin is lower banks might invest less in screening new borrowers and thus increase risk-taking (see Allen et al., 2011). According to "search for yield" models, whereas managers target certain return levels and have their compensation tied to banks' performance, a negative link between profitability and credit risk-taking emerges (Rajan, 2005).

deposits (i.e., commercial banks) may make misjudgements (about income prospects in the case of demand, or about the solvency of the counterparty in the case of supply) or behave in ways that are rational and potentially profitable from an "individual" point of view, but which, if widespread, may create excessive risks for the system. For this reason, micro and macro prudential regulation and supervision impose constraints on the composition and size of banks' balance sheets and thus on their ability to create money.

A final constraint stems from the very concept of fiat money itself. As explained in the previous sections, this type of money is characterized by the fact that it does not contain any intrinsic value (as is the case with commodity money) and does not represent a right to a real good (as is the case with representative money). The acceptance and use of money thus depend solely on the confidence of being able to use it in the future without loss of (nominal) value. Confidence is ultimately based on the ability of the issuer to maintain its value by honouring its obligations to convert it into legal money, an ability that ultimately depends on the strength and liquidity of the bank's balance sheet.

2.2. Digital Money

The landscape for payments and financial services is changing rapidly, given the far-reaching changes in technology (the digitalisation of the economy) and institutions (the increased role of non-banks in money, credit and financial markets) that have taken place over the past decade. While central bank money is still widely used in wholesale payments, the use of banknotes in retail payments is declining. New forms of financial assets (e.g., crypto-assets) and means of payment (e.g., stablecoins) have emerged in decentralized systems where such instruments are created, transferred and stored.

We will not discuss the technical aspects of these new assets, but it is important to understand their potential impact on banks and the rest of the economy, as these technical aspects may interact with those associated with the introduction of a CBDC. As discussed in detail in the Appendix, in a fractional system, banks operate at the intersection of the payment system and the credit system. The meeting point of the two systems lies in the process by which bank deposits are created, transferred and stored, and in the link they have with central bank money.

Crypto-assets are digital representations of value that use distributed financial technologies (DLTs) and cryptography to transfer ownership of individual

units (tokens) without the need for a trusted central authority or intermediary (e.g. government, bank) to verify the validity of transactions. Some crypto-assets have no intrinsic value, while others are characterized by their value being linked to that of "traditional" assets. In some cases, this can be done through tokenization, i.e. the creation of digital tokens representing "traditional" assets (either real or nominal) issued on the blockchain. In other cases, for stablecoins in particular, this can be done through other stabilization mechanisms, such as the issuance of a token with an associated right of redemption against an issuer or a portfolio of assets. If tokens are designed to be anchored to the value of very liquid assets, such as short-term government bonds, or bank deposits, they can play the role of a means of payment. However, in order to ensure value stability, it is essential that the issuer is willing to operate within a narrow regime, as non-bank stablecoin issuers would not have access to the central bank's balance sheet, would not be subject to banking regulation and supervision, and would not have a lender of last resort.

The proliferation of crypto-assets could pose challenges for central banks. For example, these instruments could lead to a loss of sovereignty in the area of payments if stablecoins linked to foreign currencies gain market share. Ultimately, the role of central bank money could be challenged to the point where it no longer serves as an effective anchor for the payment system.

These challenges have led central banks and policymakers to consider three types of response (Auer et al., 2021). The first one is regulatory, i.e. to bring new actors operating in the decentralized environment within the supervisory perimeter. The second one is to facilitate the development of private initiatives that sustain innovation and autonomy within the national borders. Finally, the last response is to become innovators and provide CBDCs that can be used for retail or wholesale payments.

The CBDC would be a form of currency with some characteristics similar to those of the type of money we have described in the previous sections.[6] First, as the name suggests, it would be a digital currency. This does not mean that, like crypto assets, it would necessarily use a decentralised ledger system with DLTs. That is one possibility. Alternatively, the new digital currency could be more like central bank reserves, based on a centralised ledger system held at the central bank. In the latter case, we speak of account-based CBDC, i.e. a kind of current account at the central

[6] Given its more far-reaching implications, we will analyse the case of a retail CBDC in what follows unless differently specified.

bank. In the former case, the CBDC would instead be value-based and would look more like a form of electronic cash.[7]

A CBDC would complement the other two types of public money because it would be more widely accessible than reserves and, unlike banknotes, would be in digital form. Because it would be issued by the central bank, the CBDC would have similar characteristics to the other forms of central bank-issued money: it could provide a safe, trusted and widely accessible digital means of payment; it would be 1:1 convertible into banknotes and deposits. Ultimately, it could promote financial inclusion, ensure the integrity of digital payments, set higher standards for security and act as a catalyst for further innovation in payments, finance and commerce in general (ECB, 2020).

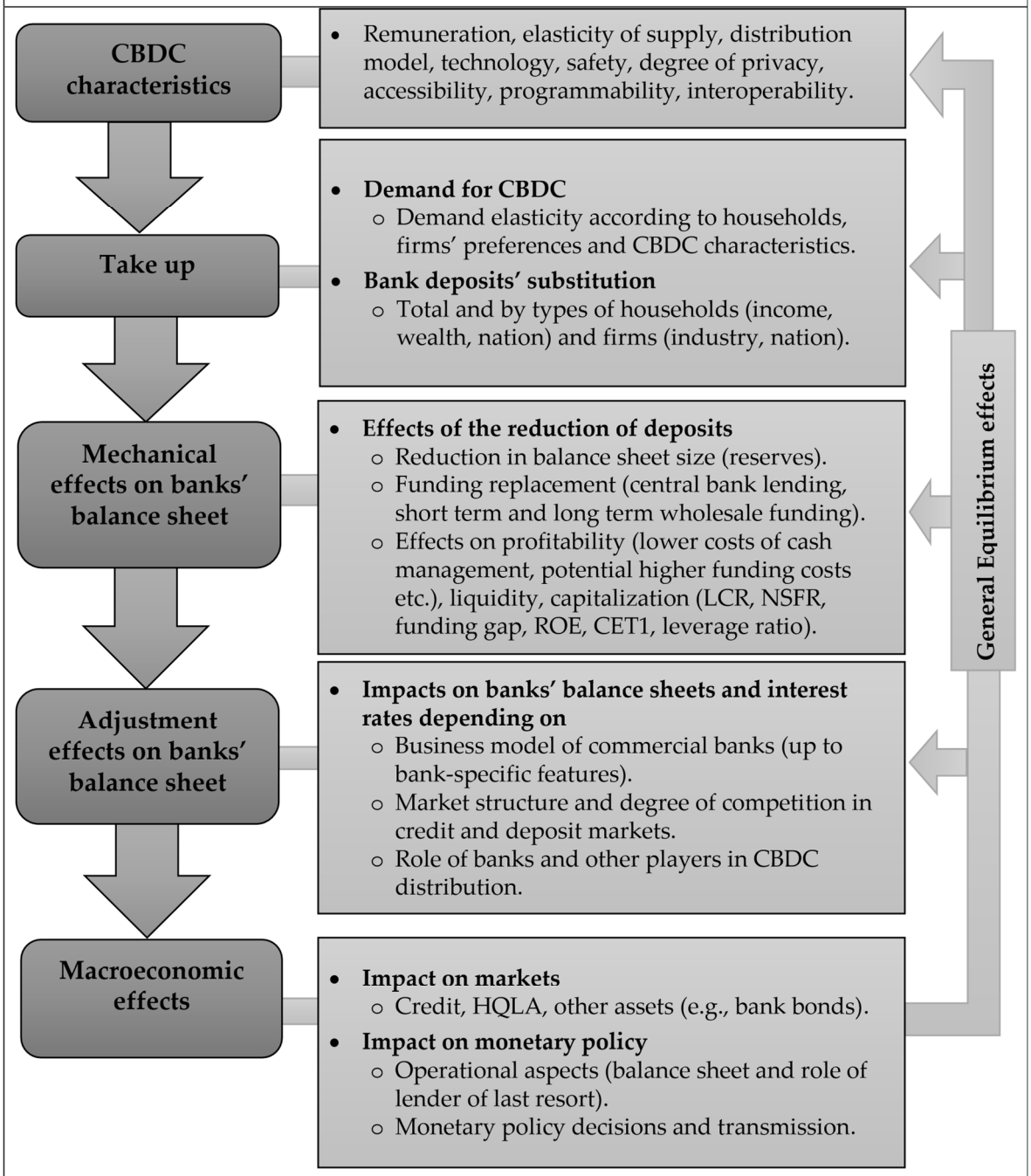
In addition to the benefits described above, a CBDC could raise several issues that the monetary authority should address, some of which are related to the role that banks play in the credit and financial markets and in the transmission of monetary policy decisions, as described in Annex 1.

In the remainder of this section we first describe the possible channels through which a CBDC could mechanically affect banks' balance sheets, depending on the different adjustment options that banks may adopt to finance the reduction in deposits. Second, we analyse the possible implications in terms of profitability, capitalization, liquidity and stability of financial intermediaries, which may induce banks to re-optimize and change the demand and supply of different forms of assets and liabilities, and trigger a series of indirect effects that may affect the broader economic system, the transmission of monetary policy and the stability of the financial system. These effects are very difficult to predict on the basis of empirical analysis, which is why the macroeconomic implications are mostly assessed using theoretical models.

Table 1 summarizes the relevant economic factors for assessing the impact on banks and the macroeconomic environment.

[7] This type of CBDC is often referred to as a "*digital token*" to indicate that, as with circulating currency or tokens, the transfer, once issued, would not take place through centralised registers but through registers in the token itself. See Urbinati et al., (2021) for a discussion on different technical options.

Table 1 – Direct and Indirect effects of CBDC on banks in steady state



2.3. CBDC implications for banks' balance sheets

The introduction of a CBDC creates a novel financial claim. As a new type of money, a CBDC could perform the dual function of store of value and means of payment. The specific characteristics assigned to it by the central bank will influence its use and diffusion by households and firms and its impact on the financial system.

In particular, the legal tender status, the off-line functionality, the security and confidentiality safeguards, the remuneration, and the introduction of holding or transaction limits will affect the take-up and the degree of substitutability with other means of payment and safe stores of value. As a result, the CBDC is likely to have an impact on household demand for banknotes and deposits.

To the extent that it is interest-free, the CBDC could become a close substitute for banknotes with no significant impact on banks' balance sheets under normal circumstances. However, there are two situations in which an interest-free CBDC may trigger large deposit outflows. First, in periods of high financial instability, it has been argued that the CBDC, even if not remunerated, could increase the risk of a flight of bank deposits (Fernández-Villaverde et al., 2021). The second is when policy rates reach the effective lower bound, in which case agents may prefer a risk-free CBDC paying zero interest to a low-risk reserve of value, such as bank deposits, with a slightly positive interest rate.

To the extent that it is interest-bearing, a CBDC could become a close substitute for retail deposits, potentially affecting the size and composition of banks' balance sheets. By modifying the composition of banks' assets and liabilities, in turn it could affect banks' capital, liquidity and maturity mismatch positions, as well as their overall size and profitability. As banks maximize profits and make decisions under regulatory and economic constraints, they would in turn adjust their balance sheets.

In general, banks and payment service providers have access to a significant amount of payers' and payees' data, such as the value, the purpose, the time and the location of a payment. The ability of a CBDC to protect privacy can vary, as any electronic payment system can shield all or some of the payee's information. For example, in account-based networks, the identity of the payer must be identified (Brunnermeier et al., 2019). Given that individuals' preferences for anonymity matter for the demand for payment instruments (Borgonovo et al., 2021), the degree of privacy of a CBDC can significantly affect its adoption. The demand for privacy in money has two main sources: (*i*) demand from individuals involved in illicit transactions (Masciandaro, 1999, Ardizzi et al., 2014), and (*ii*) licit demand by agents simply seeking protection from external scrutiny (Kahn, 2018). Indeed, new payment architectures and cryptographic procedures used to protect privacy are seen as close substitutes for cash in illicit transactions (Hendrickson et al., 2019). On the one hand, if CBDC has a low level of privacy, its users may perceive that the central bank has an excessive visibility over their actions and refrain from using it. On the other hand, a fully anonymous CBDC could have a higher take-up and

prevent potential price discrimination (see Kahn et. al., 2005, and Garratt and van Oordt, 2021). However, it could also provide a perfectly anonymous and digital means of payment for tax evaders, exacerbating the migration from deposits if commercial bank data is accessible to the tax authority, and for other illicit activities (see Rainone, 2023).

The size of these adjustments will depend on the overall CBDC take-up, which will be determined by its characteristics and household preferences; if large, it will also have important macroeconomic implications.[8] We begin by describing qualitatively how the adjustment, which takes place only along banks' assets or liabilities, further distinguished by the short (ST) or long-term (LT) duration of the financial claims involved, affects the banks' main risk and profitability measures. For the purposes of this comparison, we assume that retail deposits are a stable source of funding.[9] Moreover, in order to assess the impact on banks' interest rate margins and profitability, we generally assume that LT financial claims pay higher interest rates than ST and stable ones.[10]

[8] In practice, two possible schemes for the distribution of CBDC can be imagined: the first involves it being provided to end users by banks as is the case with cash today. The second, on the other hand, involves it being provided directly by central banks. In terms of the size and composition of banks' balance sheets in the new equilibrium, there would be no difference. In what follows we focus on the former approach.

[9] This assumption is coherent with the treatment of retail deposits in the European regulation for NSFR. In the NSFR (BCBS, 2014), the calibration of different balance sheet items reflects the stability of liabilities across two dimensions: (a) *Funding tenor*. The NSFR is generally calibrated such that longer-term liabilities are assumed to be more stable than short-term liabilities. (b) *Funding type and counterparty*. The NSFR is calibrated under the assumption that short-term (maturing in less than one year) deposits provided by retail customers and funding provided by small business customers are behaviorally more stable than wholesale funding of the same maturity from other counterparties.

[10] While this applies in general, it should be remembered that the presence of an effective lower bound (ELB) on nominal interest rates can lead to situations such as the one prevailing for most part of the 2010's when the interest rate on demand deposits was higher than those charged on other longerterm liabilities, such as LTROs and T-LTROs. It should also be remembered that commissions and fees are charged on deposits, especially at the ELB, which can imply a much lower yield.

Box A1 – Banks' liquidity regulation: the Liquidity Coverage Ratio and the Net Stable Funding Ratio

In response to the global financial crisis, the regulatory and prudential frameworks for banks has been significantly modified to limit future risks to financial stability. The Basel III accords and their implementation in Europe through the Capital Requirements Regulation (CRR) and the Capital Requirement Directive (CRD) aimed to strengthen the resilience of the banking sector to economic shocks, thereby also reducing the risk of spillovers from the financial sector to the real economy. In this box, we focus on two liquidity requirements that have been added to the regulatory framework for banks: the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR).

The LCR promotes the banks' resilience to a sudden reduction in short-term funding. The requirement aims to ensure that intermediaries have an adequate stock of assets that can be easily and immediately sold in private markets to meet their liquidity needs under a stressed scenario lasting for 30 calendar days (unencumbered high-quality liquid assets, HQLA). The total expected net cash outflows under stress are calculated by multiplying the outstanding balances of various categories of liabilities and off-balance sheet commitments by the rates at which they are expected to run off or be drawn down. The value of HQLA may be subject to haircuts, which depend on the assumption about the losses that would result from the liquidation of these assets in a short period of time and under severe stress. The LCR is calculated as the ratio of unencumbered HQLA to total expected net cash outflows under the stressed scenario and should be above 100 per cent.

The NSFR requires banks to maintain sufficient stable funding to finance their long term assets and off-balance sheet activities. A stable funding structure is intended to reduce the likelihood that disruptions to a bank's regular sources of funding will undermine its liquidity position. Stable funding is defined in terms of various characteristics that influence the stability of an institution's funding sources, including the maturity of its liabilities and the differences in the propensity of different funding providers to withdraw their money from the bank. The need for stable funding is defined using a wide range of characteristics that affect the liquidity risk profile of banks' assets and off-balance sheet exposures, including their residual maturity. The NSFR is the ratio of the amount of available stable funding to the amount of required stable funding over a one-year horizon and should be greater than 100 per cent.

The qualitative analysis adopts a static perspective, i.e. as if the banks were faced with an unexpected introduction of the CBDC, or, in other words, considering the impact on the banks' metrics compared to a situation without the CBDC. In this way, we can highlight the relevant trade-offs for each possible adjustment strategy. Table 2 summarizes the main conclusions.

Obviously, banks can combine several adjustment strategies (e.g., compensating for the decrease in deposits by partly increasing ST liabilities and partly decreasing LT assets). Indeed, a larger outflow of deposits requires banks to simultaneously consider an increasing number of binding constraints related to the tolerable values they assign to the different metrics. In the following, we explain the implications of each adjustment strategy.[11]

Table 2 – Adjustment strategies to bank deposits outflows

Adjustment strategy	Instruments	Net Stable Funding	Liquidity	Asset encumbrance	Net Interest Income	Size
Increase short-term liabilities	Repos, ST CB refinancing	-	-	+	≈	=
Increase long-term liabilities	Bonds, LT CB refinancing	≈	≈	+ (unless unsecured bond)	- (if bonds) ≈ (if CB)	=
Decrease short-term assets	CB reserves, Repos, ST securities/loans	≈	-	+	≈	-
Decrease long-term assets	Loans, LT securities	+	+ (if loans) - (if HQLA securities)	+	-	-

Note: the symbol of approximation ≈ is used when the final effect is modest and its sign actually depends on factors such as the difference between the effective maturity of deposits, usually estimated by banks via behavioural models, and that of the financial assets or liabilities used for the adjustment.

Increase in short-term liabilities

To compensate for the outflow of deposits, a bank can raise funds through short-term liabilities such as wholesale repos or short-term refinancing operations with

[11] Appendix 2 provides a more detailed description of the possible effects on the balance sheet of the banking sector and the central bank, depending on the adjustment strategies to bank deposit outflows.

the central bank. We focus on the latter instrument, because when looking at the banking system as a whole, it is not the distribution of CBDC among banks that is relevant, but the total amount of CBDC and the instrument that the banking system as a whole can use to compensate for the loss of deposits.[12]

In the absence of any adjustment on the asset side, the lower regulatory coefficients associated to newly issued ST liabilities relative to overnight retail deposits lead to a deterioration of the NSFR. The impact on the LCR is more uncertain. On the one hand, the lower expected net liquidity outflow of CB funding relative to retail deposits reduces the denominator. On the other hand, these funding sources may require banks to post also HQLA as collateral, thereby reducing the numerator and, ultimately, the LCR. Instead, the overall size of banks' balance sheet would remain unchanged, while net interest income would depend on the interest rate differential between CB funding and short-term deposits. In the low interest rate environment, for example, this differential was relatively small, while during the 2022-2023 monetary policy tightening cycle it increased significantly.

Increase in long-term liabilities

Banks can offset deposit outflows by issuing long-term liabilities (mainly bonds) or by using long-term refinancing operations with the central bank. Raising long-term funding would leave the level of the liquidity and stability mismatch roughly unchanged, as the overall size of banks' balance sheet. However, asset encumbrance would probably increase, as both covered bonds and central bank long-term refinancing operations require banks to post collateral as a guarantee. The two instruments would probably also differ in terms of funding costs, with central bank operations usually being more favourable.

Decrease in short-term assets

Banks can also reduce their balance sheet size by liquidating short-term assets such as central bank reserves, repos and/or other short-term securities (or even ST loans).

This would worsen the liquidity position, as banks reduce their holding of liquid assets; worsen the NSFR, as the balance sheet has a lower proportion of stable liabilities and short-term assets; and increase asset encumbrance, as fewer assets would be freely available as collateral. The overall balance sheet would shrink as these assets generally have low risk weights. If reserves pay negative rates and

[12] In Section 3, we will consider also the case in which banks obtain funding from foreign banks in the interbank market.

banks cannot charge negative rates or higher commissions on deposits, net interest income could benefit from such a change; otherwise, it would not change significantly if the spread between safe short-term assets and retail deposits is small enough.

Decrease in long-term assets

Liquidating an asset with an analogous maturity of retail deposits would increase the NSFR and reduce the bank 's balance sheet size.[13] As long-term assets generally carry a higher interest rate relative to retail deposits and other short-term liabilities, the medium term impact on the net interest income would be negative, especially if the bank manages to reduce the stock of long-term loans (e.g. through a securitization). In this case, the bank's liquidity ratios would improve especially if the loan counterparties are private non-financial borrowers, as these exposures are less easily sold to a third party. Conversely, a reduction in government bonds would worsen the liquidity ratio.

While these adjustment strategies imply a trade-off in terms of their impact on banks' risk and profitability metrics (with strategies that increase banks' liquidity risk having a smaller impact on profitability), some effects are not clear-cut.

Higher demand for interest rate hedges

A significant share of retail deposits are non-maturing deposits (NMD), which means that, from a financial perspective, they have a long-term duration determined by behavioural models and exhibit a sticky response to changes in short-term interest rates (Driscoll and Judson, 2013). These two characteristics lead banks to use them as a natural balance sheet hedge for fixed-rate assets (Drechsler et al., 2021). As a result, the introduction of a CBDC would reduce the availability of natural hedges and induce banks to make greater use of external hedges such as interest rate swaps and/or alter their supply of loans.

[13] Although the result on size is obvious, the one on the NSFR deserves some explanation. First, in the NSFR formula long-term assets have a required stable funding factor of 100 per cent while retail deposits have an available stable funding factor between 90 and 95 per cent. Second, even if they had the same factor, subtracting from the initial values of numerator and denominator of the NSFR an equal amount would lead the NSFR ratio to increase, as the numerator has to be larger to satisfy the NSFR requirement.

Demand for payment services

The CBDC has the explicit objective of providing a new digital means of payment for retail customers. Depending on the distribution model, banks may end up processing a lower or higher amount of payments, with uncertain effects on the overall fees related to payment services (currently around 3 per cent of total revenues for Italian banks). To the extent that banks will play a role in the distribution of CBDC to the public, their revenues may increase through the provision of services related to the CBDC. In addition, the costs associated with handling paper currency is likely to decrease, if it is gradually replaced by its digital counterpart.

2.4. The economic effects of CBDC

Analyses of the "mechanical" effects on profitability, liquidity, stability, and capitalization are mainly based on exogenous take-up scenarios and quantitative assessments using bank balance sheet data (see Section 3 for a description of the main results in the literature). These studies adopt a static perspective such as that used in Section 2.1. Instead, the economic implications of the reactions of banks and other economic agents to such scenarios are mostly assessed through theoretical analyses in a dynamic general equilibrium setting.

Generally, the studies that focus on structural effects on the credit market, payment system efficiency and welfare, use modern monetarist models (Andolfatto, 2021; Chiu et al., 2021; Assenmacher et al., 2021; Williamson, 2021) or general equilibrium models with a stylized banking sector (Agur et al., 2021) and look at the steady state. Papers that focus on possible implications for monetary policy mostly use either DSGE models (Burlon et al., 2021; Cova et al., 2022) or modern monetarist models (Assenmacher et al., 2023) and look at how monetary policy transmission would change in response to shocks; finally, those that analyse the response of banks under financial stress (individual and aggregate bank runs) and the implications for financial stability mostly use partial equilibrium models of bank runs (Böser and Gersbach, 2020; Brunnermeier and Niepelt, 2019; Fernández-Villaverde et al., 2021).

2.4.1. Structural changes in the credit and securities markets, the efficiency of the payment system and welfare

So far the literature has found different effects of a CBDC on many economic outcomes, depending on the characteristics of the CBDC and on the assumptions about the economic environment in which it is introduced. In general, most of the works find a trade-off between the improvement in the efficiency of the payment

system and the contraction in credit supply. The impact on economic growth and welfare depends largely on which of the two factors prevails.

Payment system efficiency. A general result is that the efficiency of the payment system would increase because a digital public form of retail money would help to reduce the frictions that characterize modern payment systems and the use of bank deposits as a means of payment. These frictions are mainly: (*i*) imperfect competition in deposit markets (Chiu et al., 2019); (*ii*) moral hazard and limited commitment problems that arise when banks issue demand deposits (Böser and Gersbach, 2020; Williamson, 2021); (*iii*) the limited pledgeability of banks' assets to issue deposits (Keister and Sanches, 2023); (*iv*) the relatively high cost of using private means of payment (Niepelt, 2020; Piazzesi and Schneider, 2020); (*v*) the inefficiently low remuneration of deposits as a reserve of value (Andolfatto, 2021); (*vi*) their low degree of privacy when used as a means of payment (Agur et al., 2022; Ahnert et al., 2022).

Another general finding is that CBDCs would increase the efficiency of crossborder payments. A key difference between CBDCs and the existing payment infrastructure is legacy. Many of today's frictions are rooted in differences between national payment systems, making it difficult to make large-scale changes to the infrastructures across jurisdictions. If consistent standards and coordination of CBDC designs were implemented, many of the problems inherent in today's legacy technologies and processes could be avoided (Auer et al., 2021).

Credit market. A cash-like CBDC could lead to the disappearance of cash, without significant impact on bank lending (Agur et al., 2021). A deposit-like (i.e. interest-bearing) CBDC may instead compete with bank deposits; as a result, banks may have to raise deposit rates in order to limit outflows, and this increase in funding costs may feed through to lending rates, leading to a contraction in bank credit (e.g. Agur et al., 2021; Chiu et al., 2019, Keister and Sanches, 2023; Niepelt, 2020). Similarly, the potential substitution of a low-cost unsecured funding source, such as demand deposits, with more expensive ones (such as bonds) or with secured funding (such as interbank or central bank) would also likely end up increasing the cost of loans to households and firms, especially those with longer maturities, for which the relative advantage of funding through bank deposits is higher.

Importantly, the literature points out that the effects will depend on the competitive conditions in the deposit market. If banks have no market power, the introduction of a CBDC may lead to a decrease in deposits, an increase in lending rates and a contraction in bank lending (Agur et al., 2021). The negative effects of

higher lending rates would likely fall disproportionately on the counterparties that have no or limited access to alternative sources of funding, such as debt capital markets, in particular households and small and medium-sized enterprises (SMEs). As a result, more bank-centric economies would tend to suffer a relatively higher adjustment in the aggregate volume of credit, with cascading effects on investment and output (Agur et al., 2021). If, on the other hand, banks have significant market power vis-à-vis their depositors, the introduction of a CBDC could improve economic welfare, as it would increase competition, thereby incentivizing banks to offer better services and/or higher interest rates to depositors. Importantly, the introduction of a CBDC would not necessarily crowd out bank deposits and loans. In fact, the CBDC would serve as an outside option for households, thereby limiting banks' market power and reducing their monopolistic profits, increasing bank deposits (Andolfatto, 2021) and, potentially, bank lending (Chiu et al., 2019, and Keister and Sanches, 2023).[14]

Securities markets. The introduction of a CBDC can also have a significant impact on both the supply and the demand of securities. On the supply side, banks may be able to replace some of their retail funding by issuing bonds, thereby significantly increasing their amount in the market and potentially leading to an increase in wholesale funding. Firms, especially large ones, may find it relatively cheaper to issue debt securities in the capital markets than to borrow from banks.

On the demand side, if more secured wholesale funding were used to replace deposits (Burlon et al., 2021), the demand for assets such as government bonds eligible as collateral may increase and the yields on these securities may decrease. These effects depend on the share that is already encumbered and on the collateral framework, i.e. the market and central bank collateral eligibility requirements. A similar result would be obtained if the CBDC were issued by the central bank through outright purchases of government bonds and other safe securities (Williamson, 2021). Importantly, structurally lower yields on government bonds would also reduce the return that banks earn on their HQLA portfolios.

Welfare. In general, the contraction in lending implies a reduction in investment and welfare (e.g. Agur et al., 2022; Keister and Sanches, 2023; Piazzesi and Schneider, 2020). The loss in terms of potential output and welfare may also be

[14] According to Chiu et al., (2019), lending can increase by as much as 3.55% with a properly chosen remuneration rate.

determined by the negative effects that lower bank profitability may have on bankers' monitoring efforts (Böser and Gersbach, 2020).

2.4.2. Implications for financial stability

The introduction of a CBDC may also alter the impact of idiosyncratic and systemic shocks on deposit outflows (potentially leading to bank runs) and their implications for financial stability. In general, the availability of a CBDC would make it easier for depositors to shift their holdings from the banking system to a digital form of money (i.e., the CBDC) with respect to banknotes. Most of the literature focuses on systemic runs, as depositors can always move their deposits to a bank they consider safer, regardless of the existence of a CBDC (Auer et al., 2021). In this context, the financial stability implications depend mainly on the type of models used to assess them. Partial equilibrium models tend to suggest that the introduction of a CBDC increases the probability, speed and size of bank runs. General equilibrium models suggest that, to the extent that the presence of a CBDC makes it faster and easier to convert deposits into another store of value, it reduces the moral hazard of banks. Therefore, the introduction of a CBDC may reduce the probability and size of systemic bank runs.

Individual bank runs. Since the global financial and sovereign crises, idiosyncratic bank distress episodes have mainly led to outflows of deposits to other banks, in particular to large domestic intermediaries, rather than to the conversion of deposits into banknotes, as the cost of storing a large amount of banknotes is larger than the cost of transferring deposits.[15] The conversion of deposits into CBDC would be an alternative to the transfer of deposits during an individual bank run, but with significantly different implications. The transfer of deposits under an idiosyncratic bank run would keep the overall amount of deposits in the banking system unchanged (and could eventually make the banks whose deposits increase safer) while the transfer to a CBDC would reduce the overall amount of deposits in the banking system.

Systemic bank runs. While it is true that commercial banks can become more competitive and offer higher deposit interest rates, customers' sensitivity to deposit remuneration may be relatively low in a crisis (Bijlsma et al., 2021). Therefore, some have argued that a CBDC supplied in unlimited quantities and without other

[15] Deposit outflows were compensated by an increased demand for liquidity in central bank facilities (Rainone, 2023). Under the fixed-rate full allotment regime, banks offset the liquidity outflows mainly through open market operations.

control instruments, just as for banknotes, could provide a safe heaven for depositors in the event of a systemic bank run, as it would neither create physical security issues nor be subject to scarcity-related price disincentives (Bindseil and Panetta, 2020). However, Williamson (2019) argues that it is not always true that a CBDC strictly increases fragility; it could be that, if bank runs are inevitable, they are less damaging to the economy when a CBDC is available. Fernández-Villaverde et al. (2021) support the idea that a CBDC would eliminate the run equilibrium because deposits at the central bank are not callable.

2.4.3. Implications for monetary policy

The introduction of a CBDC could affect the various stages of monetary policy transmission, from the money markets to the real economy.

Monetary policy instruments. According to some authors, the CBDC interest rate could serve as an instrument for conducting monetary policy (Bordo and Levin, 2017). The main advantage of this strategy would be in the case of the disappearance of banknotes, since the interest rate could in principle be set at (any) negative level, thus overcoming the "effective lower bound" on nominal interest rates. Nevertheless, many central banks have so far not considered charging negative rates on CBDCs and using them to reduce the effective lower bound (ECB, 2020).

According to other authors, the CBDC would become a particularly effective tool if it is used to make targeted monetary transfers from the central bank (e.g. decided and financed by the government), as it would affect the consumption and investment decisions of households and firms directly, rather than through the banking system (Davoodalhosseini, 2021).

Transmission mechanism. A universally accessible, interest-bearing CBDC could increase and accelerate the pass-through from policy rates to market rates with respect to the actual policy framework (Meaning et al., 2021; Andolfatto, 2021; Chiu et al., 2019). This is particularly true for the spread between the interest rate on retail deposits and reserves: currently, this spread is only indirectly influenced by the central bank; with CBDC, the spread would be under the full control of the monetary authority (Niepelt, 2020). Consequently, the transmission mechanism for a given change in policy instruments would be stronger (Das et al., 2023). Clearly, the lower the degree of substitutability between CBDC and bank deposits, the lower the pass-through (Agur et al., 2022).

Implications for the central bank's balance sheet. The CBDC could permanently alter the size and composition of central bank balance sheets. The issuance of a

CBDC could make expansionary policies quasi-permanent (Fraschini et al., 2021). In this context, the introduction of a CBDC could impair a tapering phase, as commercial banks could use their excess reserves to allow depositors to switch from bank to CBDC deposits. This would make (part of the) QE programmes quasi permanent. In addition, the change in the composition of the central bank's balance sheet could lead to a "CBDC trilemma" (Fernández-Villaverde et al., 2020): the central bank would find itself replacing banks in the maturity transformation, playing a central role not only in providing a new means of payment but also in lending to households and firms. This would expose the central bank to the risk of runs, which could only be avoided at the expense of its effective ability to maintain price stability.

International spillovers of monetary policy. The international use of a CBDC could increase the size and speed of international capital flows and the international spillovers of monetary policy. In particular, the international use of a CBDC could make international capital flows more volatile and increase liquidity risks for banks in both the issuing and the recipient country (Ferrari et al., 2020; IMF 2020). The monetary policy transmission will also be affected (Cova et al., 2022).

2.5. The role of the CBDC features

The degree of substitution of deposits by CBDCs and the magnitude of the micro and macro effects will depend on the characteristics of the CBDC. The introduction of a CBDC could lead to undesirable disintermediation of banks and crowd out private payment solutions. Due to their unique nature as risk-free institutions, central banks have a comparative advantage in the store of value function (Bindseil et al., 2021). Central banks therefore need to establish a CBDC that is used sufficiently as a means of payment to achieve the necessary network effects (Ahnert et al., 2022), but does not become a significant investment instrument. A number of measures have been proposed to prevent a permanent or temporary excessive flow of funds into CBDCs (Panetta, 2021). Here we briefly describe two features that are particularly important for financial stability and monetary policy, namely remuneration and holding limits. It should be noted that while these features would reduce financial stability risks associated with CBDCs, they may at the same time "distort payment efficiency in all states of nature where financial fragility is not an issue" (Auer et al., 2021).

Remuneration. A CBDC could be like banknotes, with no remuneration, or like deposits, with an interest rate. In the latter case, its interest rate would be important for monetary policy. However, a non-remunerated CBDC with no access or quantity

restrictions would mean the end of a negative interest rate policy (NIRP). Therefore, restrictions on access to and/or limits on holdings of CBDCs could be used to preserve the ability to conduct NIRP following a future issuance of a zero-yielding CBDC.

A two-tier remuneration system could be a solution to the risk of a CBDC disintermediating the banking system, while avoiding the drawbacks of hard limits (Bindseil and Panetta, 2020).[16] If short-term market rates are high enough, then zero remuneration on CBDCs provides a sufficient disincentive against excessive reliance on CBDCs as a form of investment. However, in a low interest rate environment, risk-free assets may have negative yields (apart from banknotes, which are costly and risky to store in large amounts) and banks are likely to have significant amounts of excess reserves. ECB (2020) suggests that CBDC accounts could be remunerated at a relatively favourable rate up to a certain threshold, while holdings above that threshold would earn a less favourable rate (slightly below that of other risk-free assets). Such a tiered system would prevent CBDCs from undermining monetary policy and avoid disintermediation of banks by allowing the use of CBDCs as a means of payment but discouraging their use as a reserve of value. It would also allow the central bank to act in the event of a bank run by further reducing the remuneration on second-tier CBDC if necessary. The central bank could commit never to charge negative rates on the first tier or reduce the other tier below a certain level.

Quantity limits. Introducing an inelastic supply or limiting the amount of CBDC at the aggregate or individual level has also been discussed. Panetta (2018) suggests addressing the structural disintermediation and bank run issues associated with CBDC by "setting a ceiling on the amount of CBDC that each individual investor can hold". ECB (2019b) provides a proof of concept for a CBDC solution based on distributed ledger technology, which would also allow caps to be implemented in holders' wallets, in which payments leading to excess holdings would be rejected. However, simple caps raise a number of issues. As also noted by Panetta (2018), "a ceiling on individual holdings of CBDC could limit the number or size of payments, as the recipients' holdings of CBDC would have to be known in order to finalize the payment". The risk that payments might be rejected for a reason that cannot be known in advance implies a friction that undermines the efficiency of payments. One possible way to address this concern would be to accept any payment that exceeds a certain limit of CBDC holdings, but to trigger an

[16] This was previously proposed by Panetta (2018), but he did not envisage negative remuneration for the second tier.

automatic transfer of the excess to a designated account at a commercial bank or other intermediary. Another option that has been discussed is to have heterogeneous limits, depending on the holder. For non-bank financial companies and non-financial companies, the limit could be calculated as a function of some measure of size. Non-residents, if allowed to open accounts, could also have different limits, e.g. tourists who may wish to hold limited amounts for short periods. However, heterogeneous limits cannot be easily calibrated for firms and individuals, due to differences in size and needs, and could therefore undermine the usefulness of CBDC.

Tiered remuneration or limits require CBDC holders to be identifiable, in the sense of having an account relationship, which is not compatible with a pure bearer instrument (often referred to a "token-based" CBDC).

3 Assessing the quantitative impact of CBDC on the banking system

As mentioned above, the main economic drawbacks of a CBDC are related to the fact that it could become a substitute for bank deposits and other forms of private money that ultimately rely on bank deposits for their stability (e.g., e-money backed by commercial bank money). In this way, the CBDC could jeopardize the two-tier payment system described in Section 2 and Appendix 1 and affect existing financial market structures and business models, in particular through the potential disintermediation of banks in the maturity and liquidity transformation services.

Central banks are adopting core principles and standards to guide the design of CBDCs in order to limit the financial and monetary stability implications of a digital form of public money. The Bank for International Settlement (BIS) and seven major central banks have developed three core principles for CBDCs, one of which is "do no harm to wider policy objectives" (BIS, 2020).[17] This principle states that new forms of public money should not interfere with or impede a central bank's ability to achieve public policy objectives and to fulfil its monetary and financial stability mandates. The ECB has published recommendations (ECB, 2020) stating that the digital euro should be designed to avoid its use as a form of investment and the associated risk of large shifts of private money, and that it should be made available through supervised intermediaries. The benefits of an intermediated model and the potential need for tools to mitigate the use of a CBDC as a form of

[17] The other two core principles are: "A CBDC would need to coexist with and complement existing forms of money" and "A CBDC should promote innovation and efficiency".

investment have also been highlighted by the Fed (Fed, 2022), as well as other central banks.

Implementing these principles and standards requires a clear understanding of the potential economic impact of a CBDC and of the effectiveness of design choices that could mitigate the associated risks. Ideally, central banks would need to predict a number of economic outcomes, including the overall demand for CBDC, the degree of substitutability of bank deposits and how financial intermediaries and markets would react to these changes, taking into account the potential general equilibrium effects. These predictions would in turn help central banks to design CBDC features, such as remuneration and holding limits.

To this end, central banks are in the process of developing their analytical tools to assess the quantitative impact of a CBDC. The approaches developed so far have three main features. First, they focus on the banking system, given the close substitutability of CBDC with deposits and the prominent role of banks in modern monetary systems (see Section 2). Second, they generally measure steady state effects, partly because the literature on empirical models measuring the probability of bank runs in stressed conditions is less developed than that on normal times. Third, these approaches use scenario-based simulations and simple, ad-hoc assumptions about the behaviour of users, intermediaries and markets, rather than full-fledged behavioural models. These approaches provide a range of results, rather than single predictions, and are subject to the limitations imposed by the simplifying assumptions made to obtain them.

In the reminder of this section we summarize the results from available analyses and provide an illustration of the potential impact of a CBDC on the Italian banking system.

3.1 A review of available studies and results

Empirical assessments of the potential impact of a CBDC on the banking system in the new steady state depend on three main sets of assumptions:[18] (i) the design of take-up scenarios, including assumptions about the substitution between CBDC and other forms of money; (ii) the behaviour of banks in replacing deposit outflows; (iii) the role of general equilibrium effects, such as the impact of CBDC on market interest rates for bank bonds.

[18] See Table 6 for how these set of assumptions fit within the broader conceptual framework describing the effects of CBDC on the banking system.

In all existing studies, take-up scenarios are mostly illustrative and based on ad-hoc assumptions due to the lack of empirical evidence on the potential behaviour of CBDC users.[19] The demand for CBDC is generally assumed to be up to 15 per cent of banks' total assets (ECB, 2020) or up to 40 per cent of retail deposits (Bank of England, 2021; BIS, 2021, Riksbank; 2018, Mediobanca Research, 2021; Morgan Stanley, 2021; ECB, 2022). In a few cases, scenarios are constructed using statistics on the use of cash and other forms of private money in retail payments (Bank of Canada, 2020; ECB, 2022).[20] Some studies simulate the demand for CBDC assuming the full exhaustion of a quantitative limit on CBDC holdings, such as a potential limit of €3,000 for the digital euro (ECB, 2022; Mediobanca Research, 2023; Morgan Stanley, 2021). Most of the analyses assume that the CBDC will be held by domestic households and non-financial corporations, although some analyses also consider the demand from non-bank financial intermediaries and the foreign sector. Take-up scenarios also include assumptions on the substitution between CBDC and other forms of money. All existing studies agree that the substitution of a digital form of public money with cash would be neutral for banks' balance sheets, as it would simply be a swap between two types of public money with no implication for banks' balance sheets.

The second element in assessing the impact of a CBDC is the definition of the behavioural response of banks, i.e. a set of rules specifying how intermediaries adjust the size and the composition of their balance sheets in response to deposit outflows. Most quantitative analyses change a single item on banks' balance sheets to match the reduction in deposits and then compare the results for different items. Banks are generally assumed to reduce excess reserves (Mediobanca Research, 2021) on the asset side of the balance sheet, and increase central bank refinancing (Riksbank, 2018; Mediobanca Research, 2021) or alternative market-based funding sources, such as the interbank market or debt securities (Bank of Canada, 2020; Bank of England, 2021; BIS, 2021; Riksbank, 2018; Morgan Stanley, 2021; Mediobanca Research, 2021, 2023) on the liability side. Intermediaries are generally assumed not

[19] The significant uncertainty around CBDC adoption is documented by studies that have tried to estimate potential CBDC take-up using survey data on household payment behaviour and composition of their wealth. For example, using Canadian data, Li (2021) found a wide range of potential take-up levels, ranging from 4 to 55 per cent of households' cash and deposit holdings depending on the features of the CBDC.

[20] For example, in the ECB study, a take-up scenario assumes that CBDC only replaces other retail means of payments. The total amount of CBDC demanded by households is obtained considering a substitution of 50 per cent of the value of cash, 25 per cent of the transaction value paid with cards and 75 cent of the value of the other means of retail payments and a transaction-velocity of 7 (which is almost equal to that of cash used for retail payments).

to vary other assets on their balance sheets; in particular, they do not reduce loans to the private sector.

Attempts to model the potential behavioural response of intermediaries include Bank of England (2021) and BIS (2021), which in some scenarios assume that banks raise lending rates to keep their net interest income unchanged. To our knowledge, ECB (2022) and DNB (2023) are the only studies to assume that banks minimize their costs when deciding how to rebalance their assets and liabilities. In particular, banks are assumed to use available funding instruments according to their cost ranking and subject to four constraints: (i) the amount of unencumbered assets serving as collateral; (ii) compliance with the liquidity coverage ratio (LCR); (iii) compliance with the net stable funding ratio (NSFR); and (iv) the amount of liquidity in the interbank market.[21]

Most analyses ignore general equilibrium effects, such as the increase in the cost of market funding for banks related to the increase in the supply of bank bonds, or the fact that profitability could decrease due to the competition between bank deposits and the CBDC. Prices and interest rates are usually calibrated exogenously to a fixed level. In particular, banks do not increase deposit rates to limit the outflow induced by the introduction of the CBDC. Interest rates on other sources of funding are usually assumed to be unaffected by the increase in their volumes. Limited attempts to consider general equilibrium effects are made by the Bank of Canada (2020) and the Riksbank (2018), both of which consider the case of an increase in deposit rates to limit deposit outflows.

After computing the (steady-state) adjustments in the size and composition of banks' balance sheets, the quantitative exercises usually provide an assessment of the impact on banks' profitability, in terms of changes in the return on equity (RoE). Most studies consider mainly the impact on the costs of funding, although there are few attempts to consider other sources of income and costs, such as fees and operating costs (Mediobanca Research, 2023). The overall impact on RoE is negative when deposits are mainly replaced by a more expensive source of wholesale funding; this implies that, at the time of the introduction of a CBDC, we should expect a negative relationship between (i) the impact on the RoE and (ii) the spread between the interest rate on other sources of funding for the banking system and the interest rate on retail deposits. On the contrary, the impact on profitability

[21] The observance of financial stability requirements is also contemplated in the BIS and the Bank of England analysis, with banks replacing the deposits displaced by the CBDC in such a way that the LCR remains unchanged.

is slightly positive when banks finance the purchase of CBDC mainly with excess reserves, if these are remunerated at negative rates, while it may become negative when reserves are remunerated at a positive rate; this implies that, at the time of the introduction of a CBDC, we should expect a positive relationship between (i) the impact on RoE and (iii) the amount of excess reserves.

Table 3 shows the results of some of these analyses.

Table 3 – Review of quantitative exercises on the impact of CBDC on banks' balance sheets

Source	Take-up scenarios	Replacement options for banks	Impact on ROE (bps)	Scope of the analysis
Bank of Canada, 2020	1) **5% of total deposits** (CBDC take-up equals the total amount of banknotes); 2) **16% of total deposits** (CBDC take-up equals the total amount of chequable deposits); 3) **33% of total deposits** (CBDC take-up equals the total amount of chequable and saving deposits)	i) wholesale funding	[-99; -2]	Six largest Canadian banks, 2018-2019
Morgan Stanley, 2021	1) **8% of total deposits** (€3,000 for all euro-area citizens above 15Y of age); 2) **7% of total deposits** (the minimum between 12% of HH deposits and €3,000 for all euro-area citizens above 15Y of age)	i) interbank market; ii) covered bonds; iii) senior unsecured bonds	[-17; 17]	Euro area banks, 2021
ECB, 2022	1) **between 4 and 60% of HH and NFC deposits**	i) reserves; ii) central bank funding; iii) ST secured interbank funding; iv) MT secured interbank funding; v) ST non-HQLA secured interbank funding; vi) MT non-HQLA secured interbank funding; vii) LT	n.a.	Euro area banks, 2021

		unsecured funding		
Riksbank, 2018	1) **32% of total retail deposits** (twice the amount of central bank reserves)	i) reserves; ii) central bank funding; iii) senior unsecured bonds	n.a.	Swedish banks, 2018
Mediobanca Research, 2021, 2023 NOTE: Mediobanca Research (2023) considers various sources of income and costs, including service fees and operating costs.	1) **8% of HH and NFC deposits, except repos** (€3,000 for all euro-area banked population – 290 m - and corporations -25 m); 2) **100% of HH and NFC deposits, except repos**	i) reserves; ii) central bank funding; iii) LT senior unsecured bonds	[-200; 9]	Euro area banks, 2021 and 2023
BIS, 2021	1) **between 5 and 25% of total bank assets**	i) reserves; ii) LT debt security issuance	[-87; -4]	Mixed data mainly from banking systems in the G7 countries, 2016-2021
Bank of England, 2021	1) **20% of HH and NFC deposits**	i) reserves; ii) LT debt security issuance	n.a.	Main UK banks, 2021

DNB, 2023	1) **15% of retail deposits** (€3,000 per euro-area resident);	i) central bank funding; ii) ST secured interbank funding; iii) LT secured interbank funding; iv) ST unsecured interbank funding; v) LT unsecured interbank funding.	n.a.	Euro area banks, 2019-2021

3.2 A preliminary assessment of the potential impact of a CBDC on the banking system

In this section, we illustrate the potential impact of the introduction of a CBDC on the banking system by carrying out simulations similar to those proposed in ECB (2022) using data on Italian credit institutions.

The analysis remains as agnostic as possible on the specific characteristics of the CBDC and is based on assumptions that are not necessarily consistent with the current debate on the digital euro. Thus, the scenarios on the possible take-up and substitution of banks deposits do not explicitly take into account the introduction of holding limits, the remuneration, the legal tender status, the security safeguards, the level of privacy, the method of distribution and other design choices that will likely affect the take-up and the impact of the digital euro. Some scenarios are particularly extreme (e.g. those assuming a substitution of more than 15% of total deposits). However, they may be useful for the policy debate on what the implications would be if there were features that made CBDCs highly attractive as a store of value rather than as a means of payment, and if instruments were not introduced to limit deposit substitution in this case.

Moreover, all analyses are carried out under two extreme assumptions. First, it is assumed that banks have no market power and therefore that the supply of deposits is perfectly inelastic; as a consequence, a CBDC would not affect banks' pricing decisions and would lead to a mechanical outflow of deposits. Second, the counterfactual scenario of the simulations is the status quo of an economy without the CBDC; it does not take into account potential developments in the payments market of new forms of digital private assets, such as global stablecoins, and their impact on the banking system in the absence of a CBDC.

We present two types of analysis based on prudential and market data. Section 3.2.1 focuses on the role of deposit outflows and regulatory requirements. The exercise consists in "taking a picture" of the banking system and market conditions at a given point in time (March 2023) and examining the impact of the

introduction of a CBDC on liquidity, funding stability and profitability under different hypotheses regarding (i) retail deposit outflows and (ii) the LCR and NSFR requirements. In section 3.2.2, we change the perspective and the focus of the analysis becomes the initial conditions of the market and the banking system. To this end, we take a "sequence of pictures" at different dates between June 2021 and March 2023 and see how the impact of the introduction of a CBDC on banks' profitability depends on the excess liquidity and funding costs at these initial dates. For this second analysis, we assume a deposit outflow of 10 percent and we impose that each bank maintains at least half of its buffer in excess of the LCR and the NSFR recorded at the initial dates.

3.2.1 The role of deposit outflows and regulatory requirements

We first assume that each bank experiences an outflow of retail deposits of up to 40 per cent of its deposits. This threshold would amount to around 470 € billion for the aggregate banking system in March 2023.

The banks' optimal response to the reduction in retail deposits is computed by solving a cost minimization model at bank level. Banks match the assumed outflows either by reducing the amount of reserves held in excess of reserve requirements or by increasing other forms of funding (i.e. short, medium and long term funding).[22] The objective of each intermediary is to minimize the change in net interest income subject to four constraints. First, the bank cannot reduce the amount of reserves below the reserve requirement. Second, in order to obtain liquidity in the interbank market or from the central bank, the bank must hold a sufficient amount of HQLA to use as collateral.[23] The third and fourth constraints are given by regulatory requirements associated to the LCR and the NSFR.

With respect to the latter two constraints, we considered three alternative scenarios: *i*) each bank can reduce both the LCR and the NSFR to the minimum regulatory requirement of 100 per cent; *ii*) each bank is required to maintain at least half of its buffer in excess of the LCR and the NSFR recorded in March 2023;[24] *iii*)

[22] Short-term funding has a maturity up to 6 months, medium-term funding between 6 and 12 months, and long-term funding above 12 months.

[23] We consider only HQLA collateral with a haircut equal to 0 per cent, i.e. central government assets, regional government/local authorities' assets, public sector entity assets, recognizable domestic and foreign currency central government and central bank assets, credit institution assets (protected by Member State government, promotional lenders) and multilateral development bank and international organizations' assets.

[24] For example, an intermediary with an NSFR of 180 per cent would be able to reduce it at most to 140 per cent.

each bank is required to maintain a level of LCR and NSFR equal to or larger than that recorded in March 2023. Given that the LCR and the NSFR of most banks were well above the minimum requirement in December 2022, these three scenarios are useful for discussing how the availability of liquidity buffers could affect the impact of a CBDC on the Italian banking system. Indeed, the first scenario corresponds to an environment in which there is ample liquidity in the banking system, and the third scenario corresponds to an environment in which there is little liquidity (with the second scenario in-between).

Regarding interest rates, we calibrate them using the average market values observed in March 2023 (Table 4).

Table 4 – Cost minimization problem: interest rates calibration (%)

Excess reserves	2.7
Short-term secured	2.8
Short-term unsecured	2.9
Medium-term secured	2.5
Medium-term unsecured	2.6
Long-term unsecured	4.7

Source: authors' calculations based on ECB and Refinitiv data. Note: data refer to March 2023.
NOTE: Interest rates are assumed to be the same for all intermediaries and not to change in response to changes in the demand and supply of balance sheet items. Interest rate on excess reserves is the interest rate on deposit facility. The long-term unsecured funding rate is equal to the yield on Italian bank bonds. The interest rate on short- and medium-term secured funding rates are assumed to be equal to the corresponding unsecured funding minus 10 bps. This difference is obtained by looking at Money Market Statistical Reporting (MMSR) database up to the maintenance period terminating on 20 December 2022.

We consider two illustrative cases to discuss the role of the interbank market in assessing the potential impact of a CBDC on banks' balance sheets. In the first case, we assume that banks have access to an unlimited supply of interbank funding.[25] We use this assumption to discuss the potential impact of a CBDC in a situation where interbank funding markets are not segmented and the aggregate demand of CBDC does not exceed the total amount of excess reserves in the banking system. In the second illustrative case, we assume that each bank can only access funds in the domestic interbank market[26] and that intermediaries can obtain

[25] For example, this case corresponds to a scenario in which Italian intermediaries have unconstrained access to foreign (euro-area) markets.

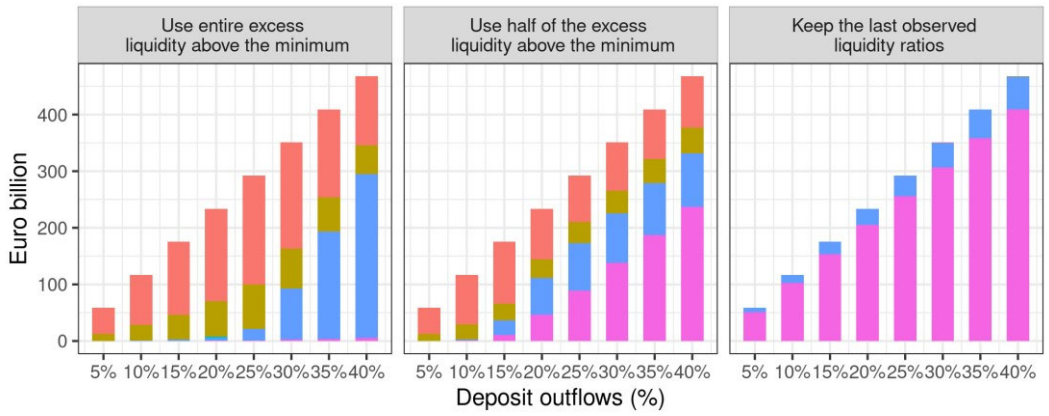
[26] In this case, we consider an additional constraint to the cost-minimization problem according to which the overall demand of reserves in the domestic interbank market is limited by the excess reserves that could be offered by Italian banks. In particular, for each intermediary that is able to match the initial deposit outflows only by using their initial excess reserve holdings, we measure the amount of liquidity that they could lend to other banks without breaching the LCR and NSFR requirements.

liquidity accessing central bank refinancing operations when the aggregate amount of excess reserves in the domestic interbank market is insufficient to meet the aggregate demand for reserves.[27] This second case hinges on a rather extreme assumption, but it is useful to discuss the circumstances in which there is a limited amount of reserves in the interbank market and banks seek support from the central bank.

The impact on liquidity and stability of funding

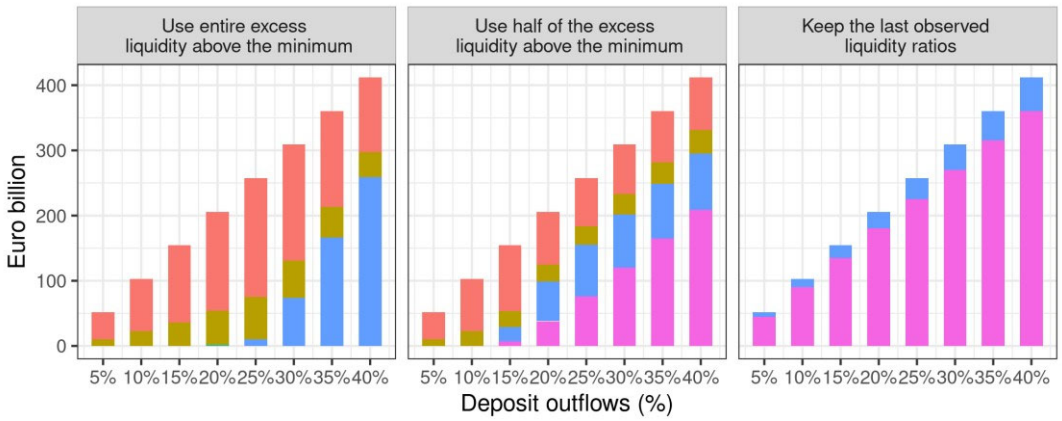
In a scenario of unlimited availability of interbank funding, if the outflow of retail deposits is relatively small (5 per cent of the total amount of retail deposits, equivalent to around €58 billion for the banking system as a whole) and banks can reduce their LCR and NSFR up to the regulatory limit of 100 per cent, the reduction in deposits would mostly be offset by a reduction in excess reserves, the least costly balance sheet item in the optimization problem (Figure 1, Panel a).

Figure 1 – Issuance of CBDC and impact on banks' balance sheets: unconstrained foreign interbank market (*percentage points, € billion*)

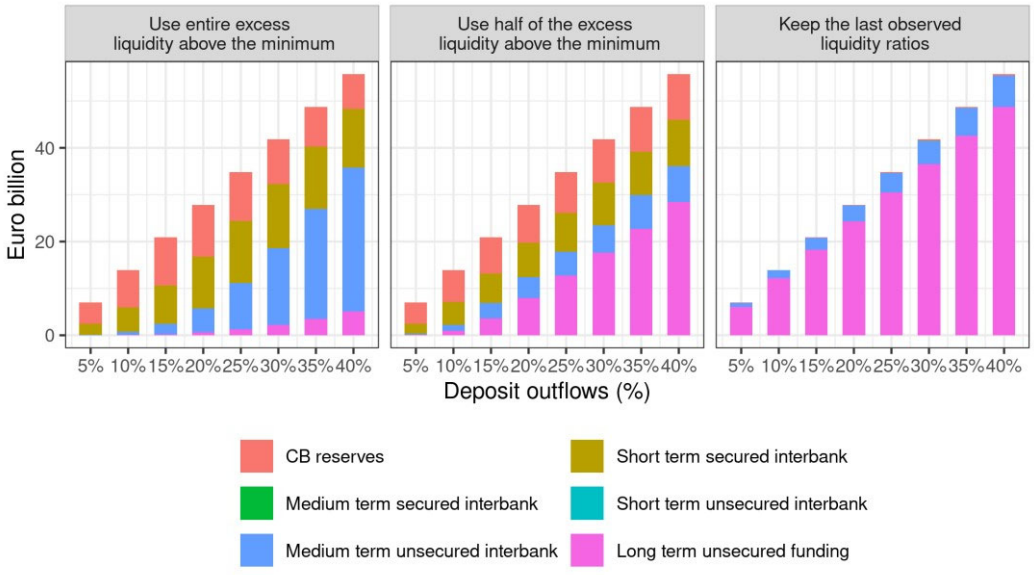


Panel a: all institutions

[27] In particular, banks would use a long-term facility similar to (T)LTROs to cover their residual demand for medium- and long-term funding, and a short-term facility similar to MRO in the other cases. We assume that banks prefer to use their HQLA to secure market funding and so use nonHQLA to obtain refinancing from the ECB.



Panel b: significant institutions



Panel c: less significant institutions

SOURCE: Elaborations based on COREP data on March 2023.

Some intermediaries without sufficient excess reserves to fully offset deposit outflows, mainly less significant institutions, would turn to the interbank market for short-term secured funding, the second less expensive instrument (Figure 1, Panel c).

In the event of a large outflow of retail deposits (up to 40 per cent of total retail deposits, equivalent to around €470 billion), more banks would turn to interbank funding. In this scenario, about half of the retail deposit outflows would be covered by a reduction in excess reserves. This is not only because, as before, the quantitative limit on available excess reserves would be reached, but also because, by reducing the amount of unencumbered HQLA, some banks would fall short of

the LCR requirement. These banks would therefore use medium-term unsecured interbank loans, the cheapest instrument that allows the bank to keep the LCR above the minimum.[28] In addition, for a very limited number of banks, the initial outflow of retail deposits would bring the NSFR below 100 per cent. They therefore resort to long-term unsecured funding to meet their stable funding needs.

If banks prefer to maintain their current buffer above the minimum LCR and NSFR requirements, we find that, regardless of the amount of deposits being replaced by the CBDC, each intermediary would use medium- and long-term unsecured funding to compensate for the reduction in required stable funding and to cover the remaining part of the initial outflow without reducing the LCR.

In an intermediate scenario, where each bank wants to maintain half of its current buffer above the LCR and NSFR requirements, the optimal solution for banks depends on the intensity of the outflow. For an initial outflow of 20 per cent of their total retail deposits (equivalent to €230 billion), 50 per cent of the reduction in the deposits would be covered by an increase in long and medium term unsecured funding, around a third by a reduction in excess reserves and the reminder by an increase in short-term secured funding.

The results are different for less significant institutions. These intermediaries, which on average have a higher LCR, can use more HQLA assets as collateral for short-term secured funding. For a higher share of deposit outflows, these instruments would cover around a quarter of the outflows.

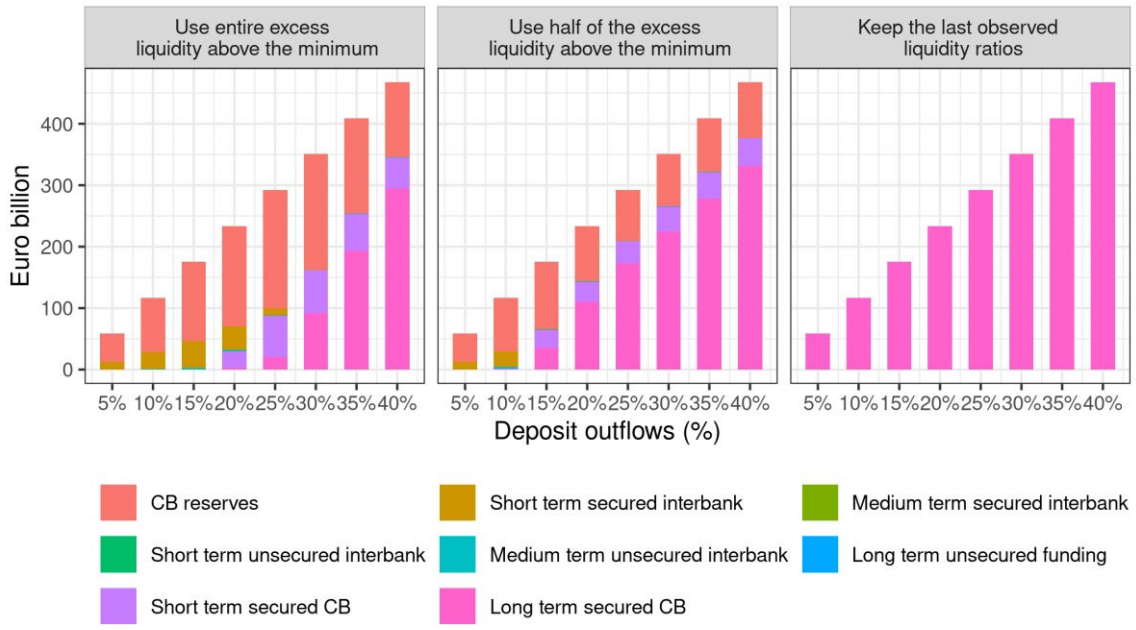
If we assume that interbank markets are segmented across national borders, the available amount of reserves in the domestic interbank market would in general be insufficient to cover banks' funding needs when the CBDC is introduced.[29] In this case the banking system would largely benefit from central bank refinancing operations. For example, under the assumption that banks use half of their excess LCR and NSFR buffers and the deposit outflows are above 15 per cent, a large fraction of banks' funding needs would be covered by central bank operations (Figure 2, middle panel).

[28] Short term funding would be cheaper but it has a higher runoff rate in the calculation of LCR net outflows and would reduce the LCR.

[29] The interest rate on short-term ECB refinancing operations is set equal to the average MRO rate in March 2023 (i.e. 3.17 per cent), while the interest rate on longer term refinancing operations is set equal to the average DFR rate (2.67 per cent), i.e. the reference rate for TLTRO operations.

Figure 2 – Issuance of CBDC and impact on banks' balance sheets: constrained domestic interbank market

(%, *€ billion*)



SOURCE: Elaborations based on COREP data.

The impact on profitability

Next, we analyse the potential impact of a CBDC on banks' profitability, under different deposit outflow scenarios. For this exercise, we assume that each bank maintains half of its March 2023 excess buffer above the minimum LCR and NSFR requirements and the interbank markets are not segmented; we calibrate banks' costs and income using data from December 2022.

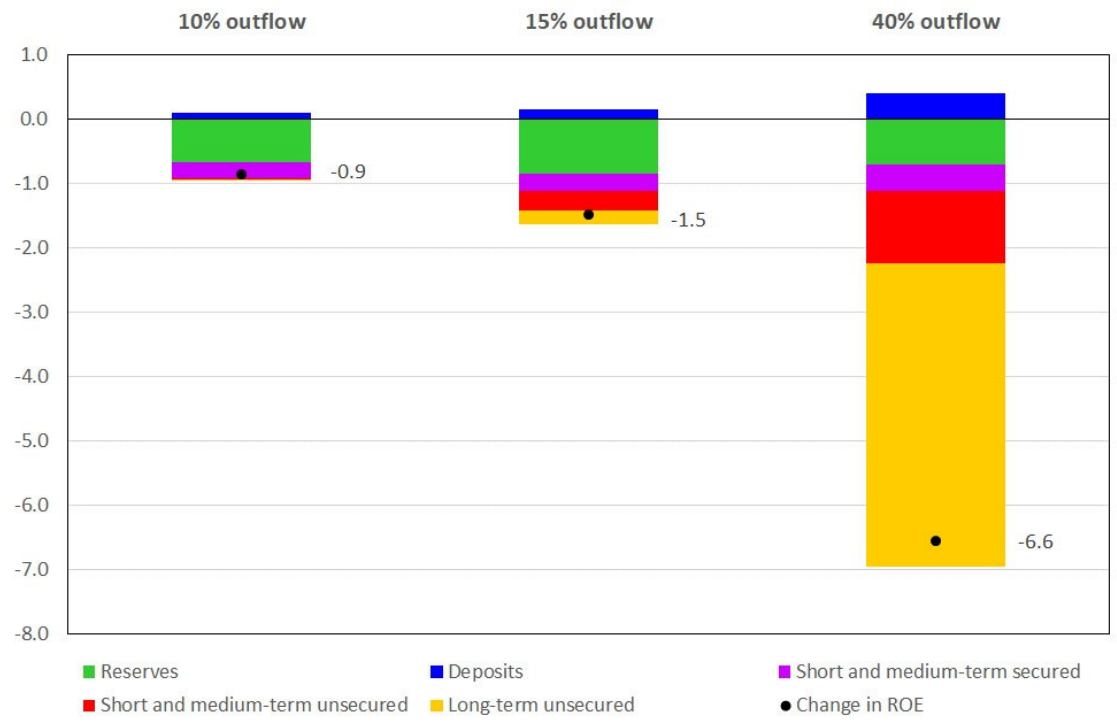
The effects largely depend on two factors: first, the difference between the interest rate on deposits and the cost of alternative sources of funding;[30] second, the amount of excess reserves.

If the deposit outflow is relatively small, the impact on profitability would be small, as banks can finance the outflow mainly by reducing reserves and/or increasing secured liabilities. In a scenario of 10 per cent deposit outflow, our simulations suggest that the RoE would be reduced by less than one percentage point from its December 2022 level (Figure 3).

[30] The average interest rate on retail deposits is computed for each bank as the ratio between the interest expense on each type of deposit and its total amount, using FINREP data.

Figure 3 – Average impact on banks' profitability

(*percentage points*)

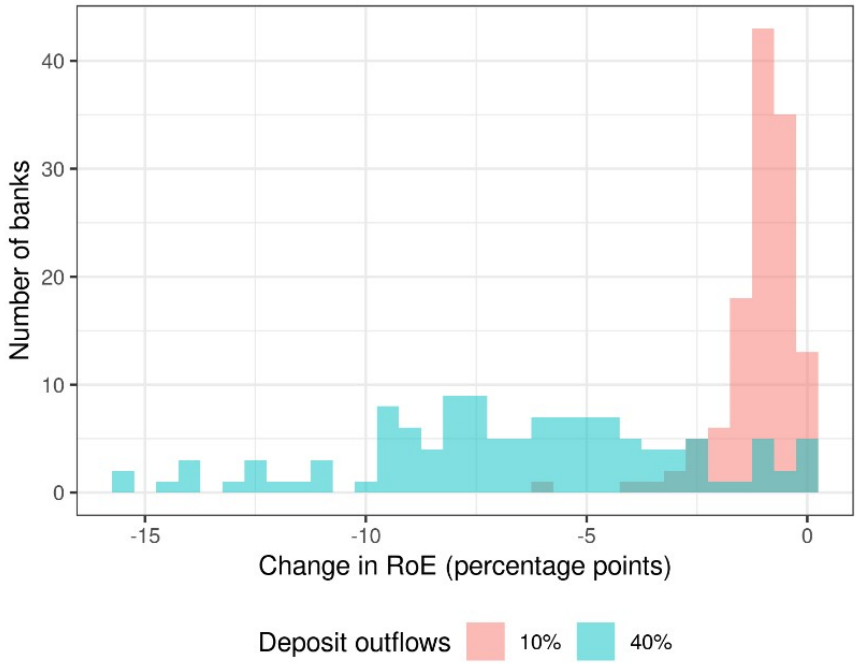


SOURCE: Elaborations based on COREP and FINREP data.

A significant impact on net interest income and on profitability would only result from a very high and unrealistic deposit outflow (25 percent or more of banks' total deposits). In this case, in fact, the banking system would also need to rely on unsecured funding, particularly long-term, which is generally the most expensive source of funding. In the extreme scenario of a 40 per cent deposit outflow, the RoE would fall by around 6.6 percentage points. The impact on profitability in this extreme scenario does not take into account the cost-effect that would result from a sharp increase in the issuance of this source of funding.

The heterogeneity across banks of the impact on profitability would increase with the size of the deposit outflow. The impact would be similar across credit institutions for a relatively small outflow, while it would be more dispersed for a larger CBDC take-up (Figure 4).

Figure 4 – Heterogeneity of the impact on banks' profitability
(*percentage points; count*)



SOURCE: Elaborations based on COREP and FINREP data.

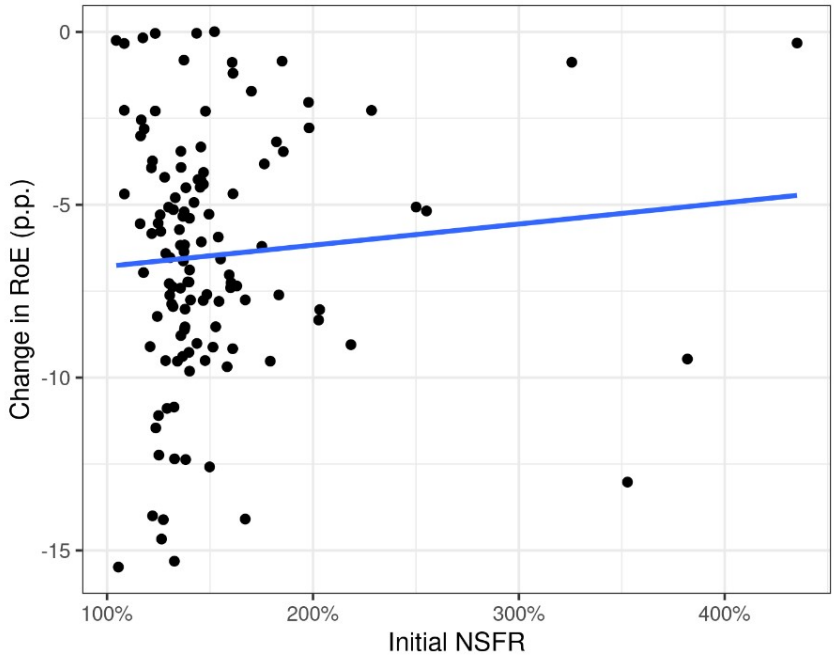
The main factor driving this heterogeneity and the emergence of negative effects on bank profitability is the recourse to long-term unsecured funding, which in turn depends on the availability of excess reserves and on the liquidity buffers above regulatory requirements, in particular for the NSFR (Figure 5).

These simulations suggest that, in order to reduce the likelihood of adverse effects on profitability, it would be important to introduce a CBDC in a context of still ample excess liquidity and large buffers of stable funding. If banks only have access to the domestic interbank market and can rely on central bank funding to fill the gap in their liquidity needs, the impact on profitability is expected to be manageable even in the case of relatively large outflows. In the simulated scenario, where the average interest rate on targeted longer-term refinancing operations (TLTROs) is zero and the one on marginal refinancing operations (MROs) is close to zero, the substitution of deposits with long-term central bank funding would have a small impact on net interest income and RoE.

Beyond the specific calibration of interest rates in this exercise, it should be emphasized that, in the event of a large deposit outflow, central bank refinancing at relatively favourable conditions would allow banks to meet their funding needs and maintain their business model without suffering severe losses in profitability and

potential negative effects on their capitalization. In this case, the collateral framework of monetary policy would clearly play an important role, as banks would need to have sufficient collateral to access central bank refinancing operations.

Figure 5 – The potential impact of CBDC on banks' profitability and banks' initial level of NSFR (*percentage points; count*)



SOURCE: Elaborations based on COREP and FINREP data. The simulated outflow of deposits is 40 per cent.

3.2.2 The role of initial excess liquidity and banks' funding costs

To further analyse the role of excess liquidity and bank funding costs, we enlarge our initial picture, considering different initial conditions.

We could have simply assumed different initial levels of excess liquidity and/or funding costs. However, it is clear that changing only some prices or quantities while leaving all other items of the banks' balance sheets unchanged would have been a biased exercise. In fact, in equilibrium, prices and quantities are simultaneously determined by supply and demand; although we do not use a general equilibrium approach in our exercises, at least the initial balance sheet composition and the relative interest rates must be consistent. In this respect, we look at balance sheets and market data at various dates between June 2021 and March 2023.

For this exercise, we assume that interbank markets are not segmented and each bank faces a 10% deposit outflow and maintains half of the buffer above the LCR and NSFR requirements recorded at the reference date. Regarding interest rates, we calibrate them using the average market values observed in each quarter between June 2021 and March 2023 (Table 5).

Table 5 – Cost minimization problem: interest rate calibration

	2021Q2	2021Q3	2021Q4	2022Q1	2022Q2	2022Q3	2022Q4	2023Q1
Excess reserves	-0.5	-0.5	-0.5	-0.5	-0.5	0.4	1.7	2.7
Short-term secured	-0.6	-0.6	-0.7	-0.6	-0.3	0.9	2.0	2.8
Short-term unsecured	-0.5	-0.5	-0.6	-0.5	-0.2	1.0	2.1	2.9
Medium-term secured	-0.6	-0.6	-0.6	-0.5	0.1	1.5	2.5	3.2
Medium-term unsecured	-0.5	-0.5	-0.5	-0.4	0.2	1.6	2.6	3.3
Long-term unsecured	0.5	0.4	0.7	1.8	3.7	4.6	4.3	4.7

Source: authors' calculations based on ECB and Refinitiv data.
NOTE: Interest rates are assumed to be the same for all intermediaries and not to change in response to changes in the demand and supply of balance sheet items. Interest rate on excess reserves is the interest rate on deposit facility. The long term unsecured funding rate is equal to the yield on Italian bank bonds. The interest rate on short- and medium-term secured funding rates are assumed to be equal to the corresponding unsecured funding minus 10 bps. This difference is obtained by looking at Money Market Statistical Reporting (MMSR) database up to the maintenance period terminating on 20 December 2022.

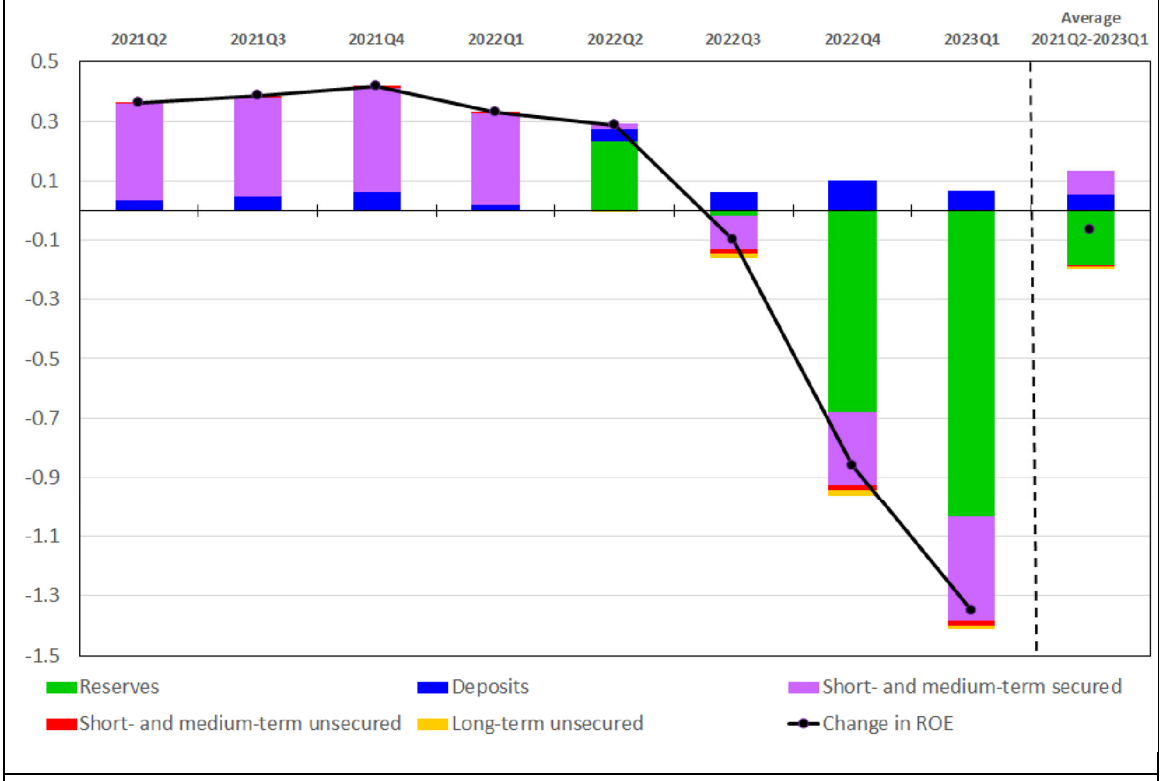
The impact on profitability turns from slightly positive to negative as excess reserves in the system decline and the spread between the cost of non-deposit bank funding and deposit rates widens (Figure 6).

More generally, Figure 6 provides insight about the potential behaviour of banks in different periods, characterized by the relative value of the interest rates on reserves and on funding sources, as shown in Table 5.

From 2021Q2 to 2022Q1, unsecured short-term interest rates were below the deposit facility rate (-0.6% and -0.5% respectively). During this period, banks would have financed deposit outflows by issuing short and medium-term funds rather than by reducing excess reserves. The reason for this is easily explained by an example. At the yields prevailing in the first quarter of 2022, a 1000€ reduction in reserves would have earned banks 5€ (given the negative return on reserves), while a 1000€ increase in short-term funding would have earned them 6€ (given the negative interest rate on short-term secured funding). In other words, since the return on reducing reserves would have been lower than the return on issuing short-term funding, banks would have mainly used the latter. With negative short-term interest rates, the overall impact of the CBDC on profitability would have been positive.

Figure 6 –Average impact on banks' profitability under different initial conditions

(*percentage points*)



SOURCE: Elaborations based on COREP and FINREP data.

In 2022Q2, short-term secured interest rates were higher than those on reserves (-0.3 and -0.5%, respectively),[31] making the use of short-term funding relatively less attractive than reserves. Therefore, banks could have used reserves to compensate for the outflow of deposits. As interest rates were still negative, the overall impact on profitability would still have been positive.

In 2022Q3, the return on excess reserves became positive but very low (0.44%), while the rate on short-term funding was much higher (0.9%). Therefore, the overall impact on profitability became negative, mainly from short-term funding (and less from reserves), although short-term funding would have accounted for a small fraction of the deposit outflow (see Figure 1).

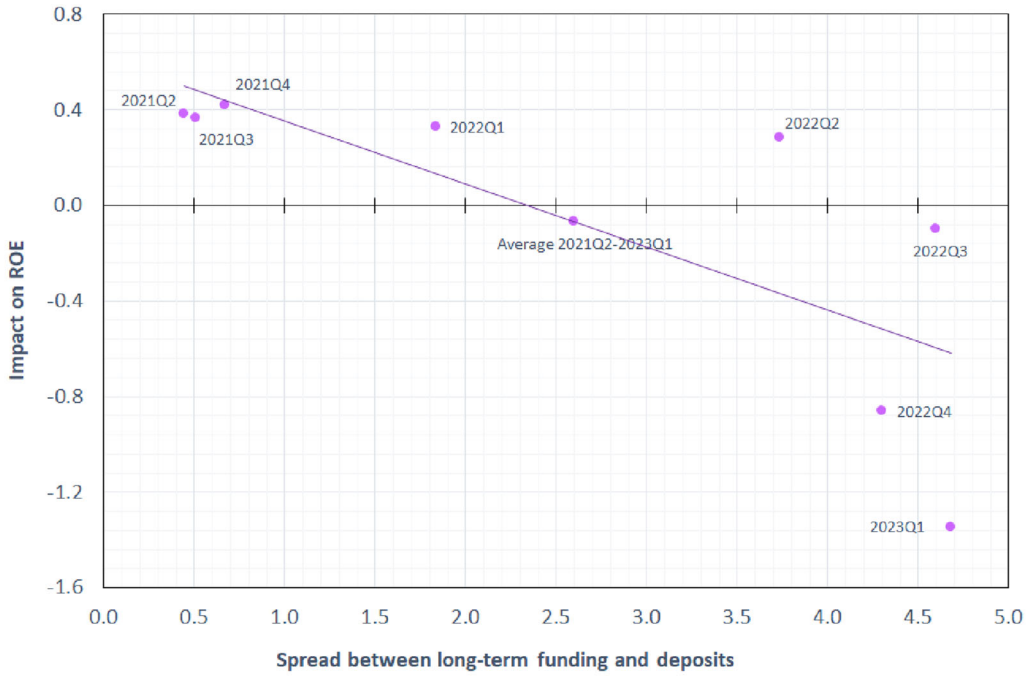
In 2022Q4 and 2023Q1 the interest rate on reserves increased significantly, although it was still lower than the interest rate on short-term funding. The negative impact on profitability would have come mainly from the decline in reserves, which would have compensated for a larger share of deposit outflows.

[31] Even after March 2022, the overnight secured interest rates were below the deposit facility rate; but here we use a 3-month rate as the short term rate and this from June onwards goes above the rate on the deposit facility.

These findings suggest three main considerations. First, the importance of the relative cost of different forms of funding in determining banks' re-optimisation decisions (figure 7).

Figure 7 – Average impact on banks' profitability and banks funding costs

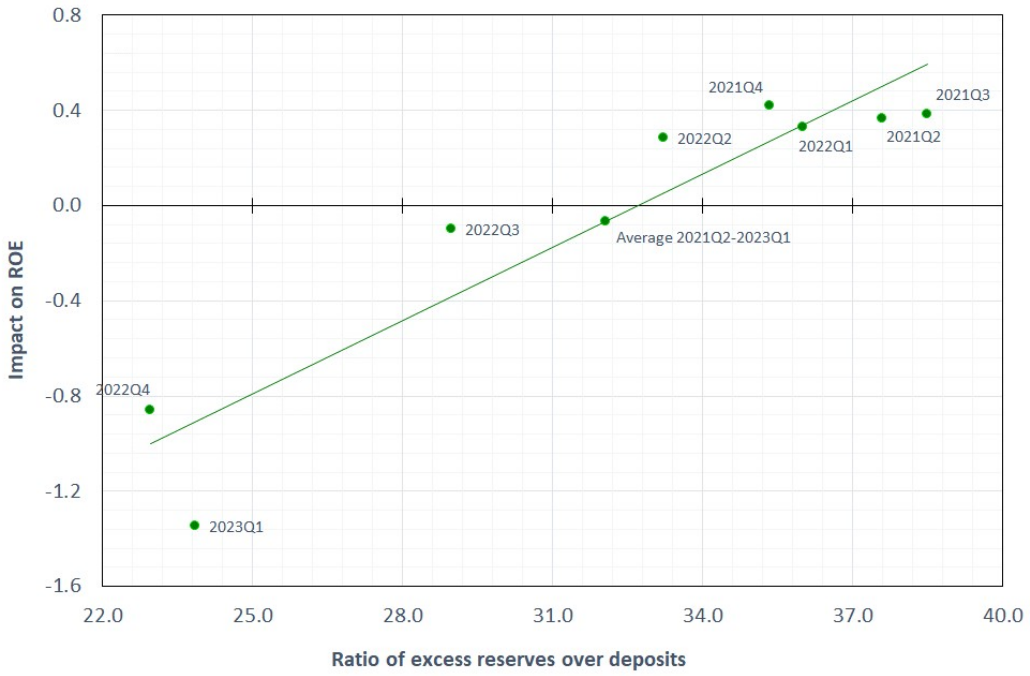
(*percentage points*)



SOURCE: Elaborations based on COREP and FINREP data.

Second, the availability of excess reserves can limit the costs of deposit substitution (Figure 8). Third, in these simulations we assume a relatively small outflow, so that banks do not need to use long-term funding. Over this period, long-term interest rates rose substantially, reflecting the tightening of monetary policy in response to the rise in inflation; this implies that the cost of RoE would be particularly high today if banks decided to finance the deposit outflow with long-term funding.

Figure 8 – Average impact on banks' profitability and excess liquidity
(*percentage points and per cent*)



SOURCE: Elaborations based on COREP and FINREP data.

4 Conclusions

More than ninety percent of central banks in the world are engaged in research and development projects related to CBDCs. In view of the potential benefits and challenges associated with a public retail digital money, this paper discusses the implications of the introduction of a CBDC for the banking system and the macroeconomic environment, also providing some illustrative exercises on the impact of a CBDC on the funding structure and profitability of banks in normal times.

The impact would depend first and foremost on the characteristics defined by the central bank. The legal tender status, the offline functionality, the security safeguards, the level of privacy, the remuneration, and the introduction of holding limits will influence overall CBDC demand and the degree of substitutability with banknotes and bank deposits. In particular, a non-interest-bearing CBDC could become a close substitute for banknotes with no significant impact on banks' balance sheets under normal circumstances. Instead, an interest-bearing CBDC could become a close substitute for retail deposits, with a direct impact on the size and composition of banks' balance sheets. If the CBDC has a low level of privacy, its

users may perceive that the central bank has too much visibility over their actions and refrain from using it. A fully anonymous CBDC, on the other hand, might have a higher take-up, but it might also provide a perfectly anonymous and digital means of payment, exacerbating deposit migration. For a given set of design choices, the impact on the banking system and, more broadly, on the macroeconomy will depend on the degree of competition in the deposit market and on how credit institutions re-optimize their balance sheets in response to deposit outflows.

To shed light on the role of bank behaviour, we performed a series of illustrative exercises on the impact of a CBDC on the funding structure and profitability of banks in normal times, using data on Italian intermediaries from June 2021 to March 2023.

Our simulations suggest that the impact of a CBDC on the funding structure of banks would be manageable if the take-up (and the deposit substitution) is less than 15 per cent of retail deposits; it could become relevant in the absence of individual holding limits, especially if there were a relatively low amount of liquidity in the banking system. The impact on the profitability of individual banks would be broadly similar if the deposit outflow were relatively small, while it would be more dispersed across credit institutions if the demand for CBDC were relatively large. Banks with low excess reserves and those that may decide to issue long-term liabilities to maintain their level of stable funding above regulatory requirements would face relatively higher costs from covering the reduction of deposits.

This paper contributes to the ongoing discussion on the potential impact of a CBDC on the banking system. Further analysis could shed light on how design choices of the CBDC would affect its overall demand, on the role of macroeconomic conditions in shaping the response of intermediaries and the interbank market to the deposit outflow induced by the substitution of private money with central bank digital money, and on assessing the effectiveness of instruments to avoid the use of public digital currencies as a form of investment.

Appendix 1 - Central banks and commercial banks in modern monetary systems

Since the aim of this paper is to analyze in detail the effects of a CBDC on the other forms of money used in market economies and on their issuers (the banking system and the central bank), this appendix provides a detailed description of the functioning of a modern monetary system.

Central bank money

Central bank money comes in two forms.

Banknotes are physical paper tokens directly available to citizens. The convertibility of commercial bank money into banknotes at par provides a monetary anchor for all private forms of money and helps to maintain public confidence in all means of exchange. As such, banknotes are part of a broader concept of the payment system. Banknotes are bearer instruments and the payment process is simple - banknotes are transferred from payer to payee. They are accepted (i.e. exchanged for goods and services) by virtue of a combination of their legal tender status and the central banks' commitment to maintaining their value.

The other type of central bank money – reserves – is intended for use in wholesale transactions. Like banknotes, reserves are safe and underpin the finality of payments. But unlike banknotes, reserves are not tangible (i.e., they are digital numbers held in ledgers at the central bank) and they are (almost) exclusively available to commercial banks. Reserves are crucial for the risk-free settlement of large-value transactions and are thus the cornerstone of financial stability (CPSS, 2003).[32]

When commercial bank money is used instead of banknotes, transfers generally take place within organised payment systems where commercial and central bank money complement each other in more complex payment chains. The paying and receiving banks are direct participants in the wholesale interbank payment system (e.g. TARGET services for the euro and Fedwire for the US dollar),

[32] In this sense, the financial crisis of 2008 served as a reminder of the value of settling in central bank money (Bindseil and Terol, 2020). The importance of settlement in central bank money was set in stone in the Principles for Financial Market Infrastructures (PFMIs) issued in 2012, Principle 9 of which recommends the use of central bank money to settle financial transactions to avoid credit and liquidity risks, where practical and available.

where reserves are held and exchanged at the settlement institution (the central bank).

The use of central bank money as a settlement asset reflects its general qualities of safety, availability, efficiency, neutrality and finality. The settlement in reserves of interbank claims generated by exchange of customer deposits is key to limiting the formation of relevant bilateral or multilateral interbank exposures and the associated counterparty and credit risk. Indeed, over the past decade, market infrastructures have steadily reduced the time lag between the initiation of payments and the final settlement in central bank money (the diffusion of instant payments is one example).[33]

The main channels through which central banks issue reserves are by granting secured loans to the banking system (refinancing operations) and by purchasing financial assets in secondary markets (outright purchase operations). When the central bank lends reserves to the banking system, the size of the balance sheets of both the former and the latter increases (Table A1).[34]

Table A1 - Creation of reserves through loans to the banking sector

Central Bank			**Banking system**	
Assets	**Liabilities**		**Assets**	**Liabilities**
Gold	Banknotes		**CB Reserves +**	Deposits
Securities	**CB Reserves +**		Banknotes	Bonds
CB Loans +	Treasury account		Loans	**CB Loans +**
Other assets	Capital		Securities	Capital

The creation of reserves through outright purchases can be either direct by the banking system, when the securities purchased were held by banks, or indirect, when the securities were held by the non-bank private sector (including both nonbank financial institutions and the non-financial sector). The former implies a change in the composition of the banking sector's assets (increase in reserves, decrease in securities; Table A2.a); the latter also implies an increase in its size (Table A2.b).

[33] For example, TARGET Instant Payment Settlement offers final and irrevocable settlement of instant payments in euro, at any time of day and on any day of the year.

[34] The financial statements used in this section are stylized and report only the major items most relevant to the bank money creation process unless stated otherwise. We abstract from the creation of reserves through autonomous factors. The numbers are purely indicative.

Table A2 - Creation of central bank reserves through purchase of securities

(a) owned by the banking sector

Central Bank			Banking system	
Assets	**Liabilities**		**Assets**	**Liabilities**
Gold	Banknotes		**CB Reserves +**	Deposits
Securities +	**CB Reserves +**		Banknotes	Bonds
CB Loans	Treasury		Loans	CB Loans
Other assets	Capital		**Securities -**	Capital

(b) owned by the non-bank private sector

Central Bank			Banking system	
Assets	**Liabilities**		**Assets**	**Liabilities**
Gold	Banknotes		**CB Reserves +**	**Deposits +**
Securities +	**CB Reserves +**		Banknotes	Bonds
CB Loans	Treasury		Loans	CB Loans
Other assets	Capital		Securities	Capital

Commercial bank money

Similarly to central banks, the two main ways in which commercial banks create money are by making new loans and by purchasing financial assets.[35]

When a bank makes a new loan, crediting it in the form of a deposit, an exchange of obligations to provide means of payment takes place: the bank undertakes to convert the deposit into banknotes (or to transfer the deposit) at the request of the holder at any time (*at sight*); the debtor undertakes to repay the money provided by the bank according to predefined deadlines (*at term*). In this exchange, the bank is (usually) remunerated with a positive interest rate, which includes a liquidity premium, a term premium and a counterparty risk premium. The first two premia result from the fact that the degree of liquidity (acceptability as a means of payment) of a sight obligation (the deposit) is greater than that of a term obligation (the loan). The latter is justified by the fact that the probability of default of the bank, a regulated and supervised entity whose balance sheet normally consists of a portfolio of diversified assets, is (generally) lower than the probability of a default of a household or a firm.

[35] See McLeay et al., (2014).

Table A3 shows how this exchange takes place in a modern monetary system. When the bank lends to the non-bank private sector, the size of both balance sheets increases: both the bank and the non-bank private sector have created an obligation to provide each other with means of payment, respectively on demand and at maturity. Similarly, when a commercial bank buys a bond (or another financial asset) from the private sector (Table A4) it creates commercial bank money.

Table A3 - Creation of deposits granting new loans

Bank			Non-bank private sector	
Assets	**Liabilities**		**Assets**	**Liabilities**
CB Reserves	**Deposits +**		**Deposits +**	Loans +
Banknotes	Bonds		Banknotes	Bonds
Loans +	CB Loans		Other assets	Capital
Securities	Capital			

Table A4 - Creation of deposits purchasing financial securities

Bank			Non-bank private sector	
Assets	**Liabilities**		**Assets**	**Liabilities**
CB Reserves	**Deposits +**		**Deposits +**	Loans
Banknotes	Bonds		Banknotes	**Bonds +**
Loans	CB Loans		Other assets	Capital
Securities +	Capital			

The ability of banks to perform out the maturity and liquidity transformation lies in the fact that they do not operate in a *narrow* regime, but in a *fractional* one. In a fractional system, such as that which characterizes the major advanced economies, the central bank requires banks to hold a minimum percentage (fraction) of their assets in central bank reserves (*reserve requirements*) against the deposits they hold.[36]

Table A5 – which is based on the aggregate balance sheet of the euro-area banking sector and the Eurosystem – shows that in a fractional system, banks have (in general) a relatively low percentage of liquidity on their assets (central bank reserves and banknotes) and a relatively high percentage of long-term illiquid assets

[36] In a narrow system, instead, the amount of deposits should be equal to the amount of reserves.

(loans) and more liquid assets (securities); against these assets, banks issue very liquid, short-term liabilities (overnight deposits and other short-term deposits) and a relatively small fraction of longer-term liabilities (bonds and term deposits with maturities of more than two years).

Table A5 – Monetary Financial Institutions in the euro area (*tn €*)

a) June 2007

Banking Sector					**Eurosystem**			
Assets		**Liabilities**			**Assets**		**Liabilities**	
CB Reserves	0.2	Overnight deposits	3.0		Securities	0.1	Banknotes	0.6
Banknotes	0.0	Other ST deposits	3.2		CB Loans	0.5	CB Reserves	0.2
Loans	18.9	CB Loans	0.5		Other assets	0.6	Other liabilit.	0.4
Securities	5.0	Bonds & LT deposits	15.9					
Other assets	3.9	Other liabilities	3.8					
		Capital	1.6					
Total	*28.0*	*Total*	*28.0*		*Total*	*1.2*	*Total*	*1.2*

b) December 2022

Banking Sector					**Eurosystem**			
Assets		**Liabilities**			**Assets**		**Liabilities**	
CB Reserves	4.0	Overnight deposits	9.3		Securities	5.1	Banknotes	1.6
Banknotes	0.1	Other ST deposits	4.0		CB Loans	1.3	CB Reserves	4.0
Loans	23.9	CB Loans	1.3		Other assets	1.5	Other liabilit.	2.4
Securities	5.1	Bonds & LT deposits	16.1					
Other assets	6.0	Other liabilities	5.7					
		Capital	2.7					
Total	*39.0*	*Total*	*39.0*		*Total*	*8.0*	*Total*	*8.0*

NOTE: numbers obtained from aggregate balance sheet of the euro-area banking sector and the consolidated balance sheet of the Eurosystem (Source ECB); *ST deposits* means "short-term deposits" and *LT deposits* means "long-term deposits". "Other assets" include financial instruments other than loans and securities (stocks, bonds) and real assets.

Under normal conditions, the central bank's balance sheet is relatively small (Table A5.a). Its size increases when the central bank implements unconventional monetary policy measures such as asset purchase programmes or it increases its refinancing operations (Table A5.b).

Appendix 2 - Adjustment strategies to bank deposits outflows and impact on balance sheets

This annex describes the possible effects on the balance sheet of the banking sector and the central bank, depending on the adjustment strategies adopted by commercial banks in response to outflows of bank deposits.

Increase in short-term liabilities. Table A6 shows how the aggregate balance sheet of the banking system and of the central bank would change if banks finance the reduction in deposits with refinancing operations with the central bank, starting from the situation described in Table A5.a. We consider separately the balance sheets impact associated with the banking system receiving CBDC from the central bank (Table A6.a) and the (final) impact associated with the provision of CBDC to depositors (Table A6.b).

Table A6 – Reduction of deposits financed through refinancing operations (*tn €*)

(a) Step 1: the banking sector obtains CBDC through refinancing operations

Banking Sector				**Eurosystem**			
Assets		**Liabilities**		**Assets**		**Liabilities**	
CB Reserves	0.2	Overnight deposits	3.0	Securities	0.1	Banknotes	0.6
Banknotes	0.0	Other ST deposits	3.2	**CB Loans**	**3.5**	CB Reserves	0.2
Loans	18.9	**CB Loans**	**3.5**	Other assets	0.6	Other liabilit.	0.4
Securities	5.0	Bonds & LT deposits	15.9			**CBDC**	**3.0**
Other assets	3.9	Other liabilities	3.8				
CBDC	**3.0**	Capital	1.6				
Total	***31.0***	***Total***	***31.0***	***Total***	***4.2***	***Total***	***4.2***

(b) Step 2: the banking sector provides CBDC in exchange for deposits

Banking Sector				**Eurosystem**			
Assets		**Liabilities**		**Assets**		**Liabilities**	
CB Reserves	0.2	**Overnight deposits**	**0.0**	Securities	0.1	Banknotes	0.6
Banknotes	0.0	Other ST deposits	3.2	**CB Loans**	**3.5**	CB Reserves	0.2
Loans	18.9	**CB Loans**	**3.5**	Other assets	0.6	Other liabilit.	0.4
Securities	5.0	Bonds & LT deposits	15.9			**CBDC**	**3.0**
Other assets	3.9	Other liabilities	3.8				
CBDC	0.0	Capital	1.6				
Total	*28.0*	*Total*	*28.0*	***Total***	***4.2***	***Total***	***4.2***

NOTE: numbers obtained from the consolidated balance sheet of the euro-area banking sector and the one of the Eurosystem in June 2007 (Source ECB); *ST and LT deposits* means "short-term deposits" and "long-term deposits" respectively. We assume that all overnight deposits as of June 2007 are converted into CBDC (€3.0 bn). Balance sheet items that increase with respect to table A5a are in green; those that reduce are in red.

The balance sheet of the banking system would increase when it receives the CBDC, but once the CBDC is provided to households and firms, only its composition would be different, while for the central bank the size will also change.

Increase in long-term liabilities. Table A7 shows how the aggregate balance sheet of the banking system would change if banks finance the reduction in deposits by issuing covered bonds purchased by the central bank.

Table A7 – Reduction of deposits financed through bond issuance (*tn €*)

(a) Step 1: banking sector obtains CBDC through bond issuance

Banking Sector				**Eurosystem**			
Assets		**Liabilities**		**Assets**		**Liabilities**	
CB Reserves	0.2	Overnight deposits	3.0	**Securities**	**3.1**	Banknotes	0.6
Banknotes	0.0	Other ST deposits	3.2	CB Loans	0.5	CB Reserves	0.2
Loans	18.9	CB Loans	0.5	Other assets	0.6	Other liabilit.	0.4
Securities	5.0	**Bonds & LT deposits**	**18.9**			**CBDC**	**3.0**
Other assets	6.9	Other liabilities	3.8				
CBDC	**3.0**	Capital	1.6				
Total	***31.0***	***Total***	***31.0***	***Total***	***4.2***	***Total***	***4.2***

(b) Step 2: the banking sector provides CBDC in exchange for deposits

Banking Sector				**Eurosystem**			
Assets		**Liabilities**		**Assets**		**Liabilities**	
CB Reserves	0.2	**Overnight deposits**	**0.0**	**Securities**	**3.1**	Banknotes	0.6
Banknotes	0.0	Other ST deposits	3.2	CB Loans	0.5	CB Reserves	0.2
Loans	18.9	CB Loans	0.5	Other assets	0.6	Other liabilit.	0.4
Securities	5.0	**Bonds & LT deposits**	**15.9**			**CBDC**	**3.0**
Other assets	6.9	Other liabilities	3.8				
CBDC	**0.0**	Capital	1.6				
Total	*28.0*	*Total*	*28.0*	***Total***	***4.2***	***Total***	***4.2***

NOTE: numbers obtained from the consolidated balance sheet of the euro-area banking sector and the consolidated balance sheet of the Eurosystem in June 2007 (Source ECB); *ST deposits* means "short-term deposits" and *LT deposits* means "long-term deposits". We assume that all overnight deposits as of June 2007 are converted into CBDC (€3.0 bn). Balance sheet items that increase with respect to table A5a are in green; those that reduce are in red. In step 1 (panel a) the banking system issue €3.0 bn of bonds, which are purchased by the CB in exchange for CBDC; in step 2 (panel b) the banking sector gives the CBDC to the private sector in exchange for banks deposits.

The increase in long-term funding to offset deposit outflows would leave the level of the liquidity and stability mismatch broadly unchanged, as would the total size of the banking system. However, asset encumbrance would probably increase, as both covered bonds and central bank long-term refinancing require banks to

provide collateral as a guarantee. Nevertheless, the two instruments would probably differ in terms of funding costs, with central bank programmes usually being more favourable.

Decrease in short-term assets. Table A8 shows how the aggregate balance sheet of the banking system would change when banks finance the reduction of deposits with a decrease in reserves and other ST assets.

Table A8 – Reduction of deposits financed through reserves and other short-term assets (*tn €*)

(a) Step 1: banking sector obtains CBDC by selling reserves and other short-term assets to the central bank

Banking Sector				**Eurosystem**			
Assets		**Liabilities**		**Assets**		**Liabilities**	
CB Reserves	**0.0**	Overnight deposits	3.0	Securities	0.1	Banknotes	0.6
Banknotes	0.0	Other ST deposits	3.2	CB Loans	0.5	**CB Reserves**	**0.0**
Loans	18.9	CB Loans	0.5	**Other assets**	**3.4**	Other liabilit.	0.4
Securities	5.0	Bonds & LT deposits	15.9			**CBDC**	**3.0**
Other assets	**1.1**	Other liabilities	3.8				
CBDC	**3.0**	Capital	1.6				
Total	*28.0*	*Total*	*28.0*	***Total***	***4.0***	***Total***	***4.0***

(b) Step 2: banking sector provide CBDC in exchange for deposits

Banking Sector				**Eurosystem**			
Assets		**Liabilities**		**Assets**		**Liabilities**	
CB Reserves	**0.0**	**Overnight deposits**	**0.0**	Securities	0.1	Banknotes	0.6
Banknotes	0.0	Other ST deposits	3.2	CB Loans	0.5	**CB Reserves**	**0.0**
Loans	18.9	CB Loans	0.5	**Other assets**	**3.4**	Other liabilit.	0.4
Securities	5.0	Bonds & LT deposits	15.9			**CBDC**	**3.0**
Other assets	**1.1**	Other liabilities	3.8				
CBDC	**0.0**	Capital	1.6				
Total	***25.0***	***Total***	***25.0***	***Total***	***4.0***	***Total***	***4.0***

NOTE: numbers obtained from the consolidated balance sheet of the euro-area banking sector and the consolidated balance sheet of the Eurosystem in June 2007 (Source ECB); *ST deposits* means "short-term deposits" and *LT deposits* means "long-term deposits". We assume that all overnight deposits as of June 2007 are converted into CBDC (€3.0 bn). Balance sheet items that increase with respect to table A5a are in green; those that reduce are in red. In step 1 (panel a) the banking system returns all reserves it has (€0.2 bn) in exchange for CBDC; the remaining €2.8 bn are financed by banks by selling €2.8 bn of other short-term assets (which we assume for simplicity that are included in the item "other assets") to the central bank; in step 2 (panel b) the banking sector gives the CBDC to the private sector in exchange for banks deposits.

Decrease in long-term assets. Table A9 shows how the aggregate balance sheet of the banking system would change when banks finance the reduction of deposits with a decrease in long-term securities.

Table A9 – Reduction of deposits financed through a reduction of long-term securities (*tn* €)

a) Step 1: banking sector obtains CBDC by reducing long-term assets

Banking Sector				**Eurosystem**			
Assets		**Liabilities**		**Assets**		**Liabilities**	
CB Reserves	0.2	Overnight deposits	3.0	**Securities**	**3.1**	Banknotes	0.6
Banknotes	0.0	Other ST deposits	3.2	CB Loans	0.5	CB Reserves	0.2
Loans	18.9	CB Loans	0.5	Other assets	0.6	Other liabilit.	0.4
Securities	**2.0**	Bonds & LT deposits	15.9			**CBDC**	**3.0**
Other assets	3.9	Other liabilities	3.8				
CBDC	**3.0**	Capital	1.6				
Total	*28.0*	*Total*	*28.0*	***Total***	***4.2***	***Total***	***4.2***

(b) Step 2: banking sector provide CBDC in exchange for deposits

Banking Sector				**Eurosystem**			
Assets		**Liabilities**		**Assets**		**Liabilities**	
CB Reserves	0.2	**Overnight deposits**	**0.0**	**Securities**	**3.1**	Banknotes	0.6
Banknotes	0.0	Other ST deposits	3.2	CB Loans	0.5	CB Reserves	0.2
Loans	18.9	CB Loans	0.5	Other assets	0.6	Other liabilit.	0.4
Securities	**2.0**	Bonds & LT deposits	15.9			**CBDC**	**3.0**
Other assets	3.9	Other liabilities	3.8				
CBDC	**0.0**	Capital	1.6				
Total	***25.0***	***Total***	***25.0***	***Total***	***4.2***	***Total***	***4.2***

NOTE: numbers obtained from consolidated balance sheet of the euro-area banking sector and the consolidated balance sheet of the Eurosystem in June 2007 (Source ECB); ST *deposits* means "short-term deposits" and *LT deposits* means "long-term deposits". We assume that all overnight deposits as of June 2007 are converted into CBDC (€3.0 bn). Balance sheet items that increase with respect to table A5a are in green; those that reduce are in red. In step 1 (panel a) the banking sector sells €3.0 bn of long-term securities in exchange for CBDC; in step 2 (panel b) the banking sector gives the CBDC to the private sector in exchange for banks deposits.

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